VOL. XIII. JANUARY, 1902.

Established by BENJAMIN SILLIMAN in 1818.

THE AMERICAN JOURNAL OF SCIENCE.

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FOURTH SERIES.

VOL. XIII—[WHOLE NUMBER, CLXIII.]

No. 73.—JANUARY, 1902.

NEW HAVEN, CONNECTICUT.

1902.

THE TUTTLE, MOREHOUSE & TAYLOR CO., PRINTERS, 125 TEMPLE STREET.

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AMERICAN JOURNAL OF SCIENCE

[FOURTH SERIES.]

ART. I.—*An Experimental Investigation into the "Skin"-effect in Electrical Oscillators;* by C. A. CHANT.

1. *Introductory and Theoretical.*

THE first explicit reference to the fact that, when a conductor is subjected to a periodic electromotive force, the current is not uniformly distributed over a cross-section of the conductor, is to be found in Art. 690 of Maxwell's Electricity and Magnetism. Upon obtaining the equation connecting the impressed electromotive force with the effective electromotive force and the inductive electromotive force he introduces terms which "express the correction of this value [of the inductive electromotive force] arising from the fact that the current is not of uniform strength at different distances from the axis of the wire. The actual system of currents has a greater degree of freedom than the hypothetical system in which the current is constrained to be of uniform strength throughout the section. Hence the electromotive force required to produce a rapid change in the strength of the current is somewhat less than it would be on this hypothesis."

It is quite certain, however, that Maxwell did not foresee the great interest and importance which the subject was destined soon to develop.

In a series of papers written between 1884 and 1887 Heaviside* dealt with the entire question of the propagation of electric currents into conductors and of magnetization into cores when produced by a periodic electromotive force. He was one of the first to insist that the action should be considered as entering the conductor from the surrounding dielec-

* Electrical Papers, vol. i, pp. 353, 429; vol. ii, p. 168.

tric. He compares the transmission of the effect into the metal to the transmission of motion into the inner portions of liquid in a cylindrical vessel when the vessel is given a rotatory vibration about its axis.

Especial attention was drawn to the subject by Hughes,* who treated the question experimentally.

In 1886 Rayleigh† published his well-known paper in which he obtained expressions for the resistance and self-induction of a straight conductor carrying a periodic current. For very rapid oscillations the resistance

$$R' = \sqrt{(\tfrac{1}{2} p l \mu R)} \qquad (1)$$

in which l is the length of the conductor, μ its magnetic permeability, R its resistance to steady currents and $p = 2\pi n$, where n is the frequency.

In 1890 Stefan,‡ in a paper on electric oscillations in straight conductors, also obtained formulas for the resistance and self-induction. With very high frequency his expression for the resistance is

$$R' = R\pi a \sqrt{\frac{n\mu}{\sigma}} \qquad (2)$$

where a is the radius of the conductor and σ its specific resistance. This formula is equivalent to that given by Rayleigh. He remarks that for very great frequencies metallic conductors act much as though without resistance, but electrolytes behave very differently on account of their very high resistance. He finds that for a cylindrical copper conductor 1^{cm} in diameter, with a frequency of 50 millions, the current density at a depth of $0{\cdot}004^{cm}$ is only 1/100 of that at the surface; while for a tube of equal size of carbon disulphide the current density at the center is but 0·8 per cent lower than at the surface,—in other words, the current is practically uniform.

If, now, the action enters the conductor from the surrounding dielectric and is prevented from penetrating very far by the rapidity of the oscillations, it is evident that very thin layers of metal should be sufficient to ward off electrical undulations, either by absorption or reflection.

In a paper published in 1889 Hertz§ described experiments made to find out how thick a metallic film was needed to screen from his rapid oscillations. Tinfoil, Dutch metal and gilt paper acted perfectly. The thickness of the metal on the latter he estimated at $1/20^{mm}$ though it was probably much

* Jour. Soc. Tel. Engineers, Jan. 28, 1886.

† "On the Resistance and Self-induction of Straight Conductors," Phil. Mag., May, 1886, p. 382; Scientific Papers, vol. ii, p. 486.

‡ Wied. Ann., xli, p. 400, 1890.

§ Electric Waves, p. 160.

less than that amount. Chemically deposited silver failed when the film was so thin as not to be opaque to light. The thickness of this film he places at less than $1/1{,}000^{mm}$. It was probably not 1/10 of that thickness and, moreover, hardly continuous metal. He remarks that the action of the waves scarcely penetrates farther into the wire than does the light which is reflected from its surface. Similar experiments on the screening effect of extremely thin metal leaf are given by Lodge and others.

A calculation of the superficial shell effective in the reflection of Hertzian oscillations is given by Poincaré,* who finds the thickness at which the effect is $\frac{1}{e}$ of its amount at the surface,

for frequency, $n = 50 \times 10^6$, thickness $= 0{\cdot}002^{cm}$;
" " $n = 500 \times 10^6$, thickness $= 0{\cdot}006^{cm}$.

This estimate is probably too high.

J. J. Thomson has treated the "skin"-effect with considerable fulness. In a note appended by him to Art. 690 of the third edition of Maxwell† he obtains as the resistance per unit length of the conductor

$$R' = \left(\frac{\mu p \sigma}{2\pi a^2}\right)^{\frac{1}{2}} \qquad (3)$$

where the symbols have the meanings given above. This, again, is the same as the values obtained by Rayleigh and Stefan.

We can obtain the relative current densities at different depths below the surface for any given frequency in the following way. Stefan‡ has shown that if w be the component of the current in the direction of the axis of z, and if it does not vary with z, the equation

$$\frac{dw}{dt} = \frac{\sigma}{4\pi\mu}\left(\frac{d^2w}{dx^2} + \frac{d^2w}{dy^2}\right) \qquad (4)$$

must be satisfied.

When the depth to which the action penetrates is small the effect of curvature of the surface may usually be neglected, in which case (4) may be replaced by

$$\frac{dw}{dt} = \frac{\sigma}{4\pi\mu}\frac{d^2w}{dx^2} \qquad (5)$$

* Oscillations Électriques, p. 246 and fol.
† See also Recent Researches, p. 246 and fol.
‡ Sitzungsberichte der Wiener Akad. der Wiss., xcv (II), p. 917, 1887.

This is Fourier's well known equation of diffusion, which Lord Kelvin* has shown to be applicable to the motion of a viscous fluid, as of closed electric currents within a homogeneous conductor, of heat, of substances in solution, of electric potential in the conductor of a submarine cable; and, indeed, to every case of diffusion in which the substance concerned is in the same condition at all points of any one plane parallel to a given plane.

Suppose, now, the periodic current at the surface to be represented by

$$w = \mathrm{I} \sin pt \tag{6}$$

We have to solve (5) subject to the conditions,

$$w = \mathrm{I} \sin pt, \text{ when } x = 0 \tag{7}$$
$$w = 0 \quad \text{“} \quad t = 0 \tag{8}$$

The solution is

$$w = \frac{2}{\sqrt{\pi}} \mathrm{I} \left[\sin pt \int_{\frac{x}{2\kappa\sqrt{t}}}^{\infty} e^{-\beta^2} \cos \frac{px^2}{4\kappa^2\beta^2} d\beta - \cos pt \int_{\frac{x}{2\kappa\sqrt{t}}}^{\infty} e^{-\beta^2} \sin \frac{px^2}{4\kappa^2\beta^2} d\beta \right] \tag{9}$$

wherein $\kappa^2 = \sigma/4\pi\mu$.

As t increases the condition of affairs approaches a “permanent” state, and then (9) reduces to†

$$w = \mathrm{I}\, e^{-x\sqrt{\frac{2\pi\mu p}{\sigma}}} \sin \left(pt - x\sqrt{\frac{2\pi\mu p}{\sigma}} \right) \tag{10}$$

At the surface, i. e. when $x=0$, the maximum value of the current is I. It becomes $\frac{1}{e}$ of this value at a depth

$$x = \sqrt{\frac{\sigma}{2\pi\mu p}} = \frac{1}{2\pi}\sqrt{\frac{\sigma}{\mu n}} \tag{11}$$

This depth J. J. Thomson‡ and Poincaré§ take as the thickness of the “skin.” The difference in phase between the current at the surface and that at this depth is easily obtained from (10), and is

$$1 \text{ (radian)} = 57{\cdot}3^\circ$$

For high frequencies this thickness becomes exceedingly small, and an object of the present investigation was to see if an oscillator behaved differently when the metal constituting

* Report of British Assoc., 1888, p. 571.
† See Byerly's Fourier's Series and Spherical Harmonics, Art. 51.
‡ Recent Researches, pp. 260, 281. § Oscillations Électriques, p. 252.

it was thinner than this "skin"; and if so, what was the critical thickness in any particular case.

In the experiments to be described oscillators were used with frequencies approximately 375, 825, 2000, 3200 millions per second, respectively. Substituting these values for n in the above value (11) for x; and taking $\mu=1$, $\sigma=1600$, approximately, for copper or gold, 13,500 for platinum and 4,770,000 for electric-light carbon, we obtain the following table:

TABLE I.

Frequency n Millions.	Thickness of "skin." Copper. cms.	Platinum. cms.	Carbon. cms.
375	0·00033	0·00092	0·01749
825	0·00022		
2000	0·00014		
3200	0·00011		

We can obtain an approximate value for the thickness of the "skin" in another way. Suppose the conductor to be a circular cylinder. From Stefan's formula (2)

$$\frac{R'}{R} = \pi a \sqrt{\frac{n\mu}{\sigma}};$$

and assuming that, as with steady currents, the resistance is inversely proportional to the area of the section used by the current, the oscillatory current must occupy the R/R′th part of the section. Since this portion is a thin layer next the surface we have

$$2\pi a x = \frac{R}{R'} \times \pi a^2,$$

$$= \pi a \sqrt{\frac{n\mu}{\sigma}} \times \pi a^2,$$

$$\text{and } x = \frac{1}{2\pi} \sqrt{\frac{\sigma}{n\mu}};$$

which turns out to be precisely the value we obtained before (11).

Hertz* stated that, as far as he could observe, the nature of the metal out of which his *resonator* was formed had no influence upon the phenomena, but experiments by Bjerknes† did not confirm this conclusion. He found the efficiency of the metals: copper, brass, silver, platinum, nickel, iron, to be in the order in which they are here named. By depositing elec-

* Electric Waves, p. 45.
† Wied. Ann., xlviii, p. 592, 1893.

trolytically on the surface of a metal forming a resonator a shell of another metal, he determined what thickness he must add in order that the resonator should behave as though formed of the second metal. He used an electrometer method, and his results are shown in the following table:

TABLE II.

	Original Reading.	Final Reading.	Thickness of Layer.
Copper on iron	13·4	105	0·012^{mm}
Zinc on iron	13·4	71	0·016 "
Zinc on copper	100	80	0·012 "
Nickel on copper	100	40	0·010 "
Cobalt on copper	100	10	0·003 "
Iron on copper	100	10	0·003 "

The wave-length used by Bjerknes was 420^{cms} and the frequency, therefore, about 70 millions per second.

I have not been able to find any record of experiments on the thickness of the effective portion of the metal of an *oscillator* except by Preece and Righi.

Tho former, in describing experiments made in conjunction with Marconi on signaling without wires, says:*

"The distance at which effects are produced with such rapid oscillations depends chiefly on the energy of the discharge that passes. A six-inch-spark coil sufficed through 1, 2, 3, up to four miles, but for greater distances we have used a more powerful one—one emitting sparks 20 inches long. It may be pointed out that this distance increases with the diameter of the spheres and it is nearly doubled by making the spheres solid instead of hollow."

He used the regular Righi oscillator with 10^{cm} spheres sparking in vaseline oil, from which, he says, there were emitted waves 120^{cms} in length, with a frequency of 250,000,000 per second. How this wave-length was determined is not given.

Righi states:†

"Finally I made the perhaps unlooked-for observation that an oscillator composed of hollow spheres is less effective than one such of massive spheres. For example, when the oscillator had massive spheres of about 4^{cms} diameter, the action on a resonator first ceased at about 11 meters; while, on the other hand, it ceased at about six meters when these spheres were replaced by hollow ones of equal external diameter and about 1·5^{mm} of wall-thickness. Two others with yet decidedly thin-

* Proc. Royal Inst., vol. xv, p. 472 (1897).

† Righi, Optik der elektrischen Schwingungen, pp. 14, 15.

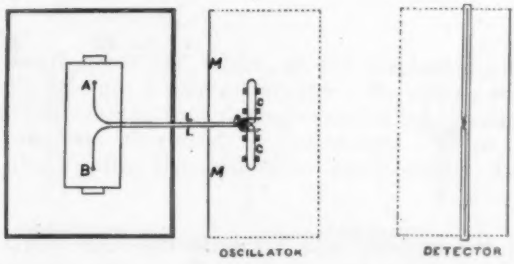
ner walls gave still smaller effects. The knobs connected to the machine* might, however, quite as well be hollow as solid, and also, within certain limits, might be of less or greater diameter without the efficiency of the oscillator being thereby affected."

As just remarked, these are the only references to the subject that I have found. Indeed, considering the importance of the oscillating doublet, it is somewhat surprising that so little has been done in the direction of a satisfactory theory of it.

2. *The Oscillators.*

The oscillators were of two types,—cylindrical and spherical, respectively. The cylinders were circular in section with hemispherical ends; and were $2{\cdot}5^{cms}$ in diameter and $12{\cdot}5^{cms}$ long. For exciting the oscillator an induction coil capable of giving a $12{\cdot}5^{cm}$ spark was used. It was placed in a metal-lined box and connections were made to it as follows.

1



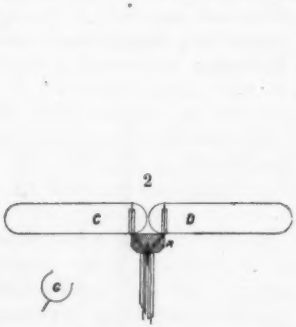
The cylinders C, D (figs. 1, 2) were placed along the focal line of a parabolic reflector M, made of sheet zinc, being held in position by wooden supports hollowed to receive them. To the ends of the wires LL, were soldered strips r, r of brush copper about 5^{mm} wide bent into circular form as shown in G (fig. 2). The ends of the cylinders were slipped into these copper holders, and a rubber band placed about the holder drew it closely to the cylinder, thus insuring good and ample contact. The wires were then led through a wooden block R (shown in fig. 2), into which they were securely wedged, and then through small glass tubes firmly held together by rubber tape; and were finally joined to A and B, the terminals of the secondary of the coil. The glass tubes passed through openings in the mirror M and the box. By this arrangement a pair of cylinders could be removed and another pair substi-

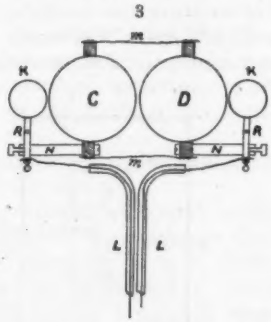
* Influence electrical machine.

tuted for them, while the connections remained precisely the same.

The spark gap was always the same for the cylinders, being about $0{\cdot}7^{mm}$ long.

The spherical oscillators were of the Righi pattern. The spheres C, D (fig. 3), were held in circular discs of hard rubber, in which openings had been turned to receive them, by melting paraffine about them. The smaller knobs, K, K, were on the ends of jointed rods, R, R, which were held in hard rubber rods N, N, rigidly fastened to the disks carrying the spheres. By this means the knobs could be adjusted to the spheres and would remain so when the spheres were adjusted to each other. To allow this latter to be done one disc was held to the horizontal support beneath by a screw passing up





through the support into it, while the other could be slid along the support by a screw. The entire arrangement is shown in fig. 4. The spheres were of three sizes. With those $2{\cdot}5^{cms}$ and 4^{cms} in diameter, knobs K, K of diameter 19^{mm} were used. When the spheres had a diameter of 10^{cms}, the knobs had a diameter of 37^{mm}.

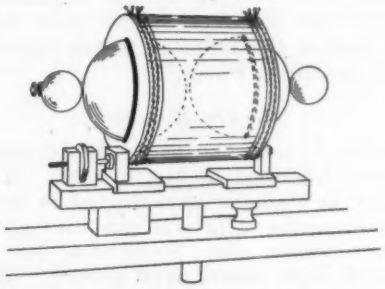
The membrane, *m*, *m*, was first softened by soaking for a few minutes in water and glycerine, and was then securely bound to the circumference of the hard rubber discs by cords which rested in grooves made to receive them. The membrane was such as is used as a container for the familiar "Bologna sausage," and was obtained at a large packing house. It made a perfectly oil-tight vessel, fig. 4, the largest oscillator being in action for hours without a single drop of oil escaping.

The oil used was described as *white liquid vaseline*.

When in operation the oscillator was placed in the parabolic reflector on a suitable support, seen in fig. 5, and was connected to the coil by wires, L, L, passing through tubes as in case of the cylinders.

The interrupter was that used by G. W. Pierce with his radio-micrometer.* It consisted of a platinum-tipped rod which, by means of a fan-motor, was rapidly plunged into and withdrawn from a cup of mercury, the surface of which was kept clean by a stream of water continually flowing over it. In series with the interrupter was a pendulum contact-maker. The metallic rod of the pendulum carried a platinum wire

4



soldered to its lower end, which, as the pendulum swung to and fro, dipped into a mercury trough. By raising or lowering the pendulum, the time during which it was immersed in the mercury was shortened or lengthened. This was so adjusted that whilst the pendulum made circuit during a

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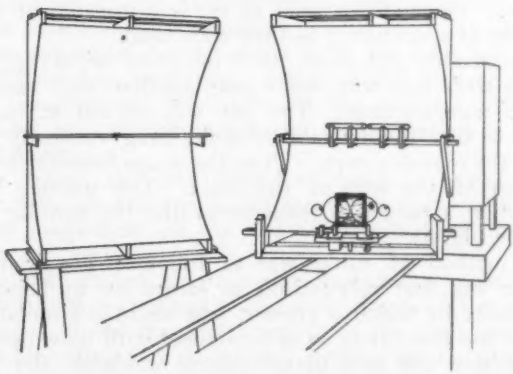


single semi-oscillation, the motor-break made about six interruptions. In addition an ordinary key was in circuit. This was pressed down while the pendulum made any desired num-

* This Journal, vol. ix, p. 252, 1900.

ber of vibrations. For most of the work the key was depressed for 10 swings of the pendulum, that is, for about 60 interruptions of the coil. Thus in the primary circuit the current traversed in succession the primary of the induction coil, the motor-break, the pendulum rod into the mercury and the circuit-key. The battery consisted of 10 storage cells arranged in two banks in multiple, i. e., giving 10 volts of E.M.F.

The parabolic mirrors, both for oscillator and receiver, were 75^{cms} high, 60^{cms} wide, and had a focal length of $12{\cdot}5^{cms}$. At first reflectors of but 5^{cms} focal length were tried, but they were entirely useless, the reflected waves apparently destroying completely the direct waves.*

3. *The Receiver.*

As a receiver I used the magnetic detector devised by Rutherford† and described by him in 1896. A few inches of iron wire $0{\cdot}14^{mm}$ in diameter were dipped in melted paraffine and, after cooling, the wire was cut into about 20 pieces. Holding these together, about 90 turns of fine (No. 40) insulated copper wire were wound upon about 1^{cm} of their length; and after the protruding ends of the iron wire had been cut off and the fine wire had been soldered to heavier copper wires, the helix with its iron core was mounted in the end of a small glass tube, the connecting wires being drawn through the other end of the glass tube. The helix was kept in place by simply dipping the tube in melted paraffine and then allowing it to cool. The entire arrangement is shown (half size) in fig. 6. The helix is seen at H, and the ends of the wire are shown at *e*, *e*, curved as they were used.

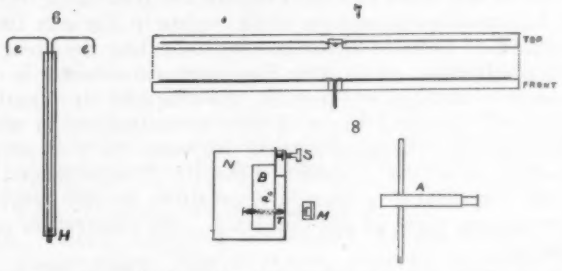
On a wooden rod about 65^{cms} long two wires (fig. 7) were fastened with soft wax, their near-together ends terminating in small mercury cups. The bar was cut out at its central portion so that the detector D could hang vertically with its ends in the mercury cups. Thus the wings became electrically a portion of the wire of the helix. The wooden bar was mounted in a parabolic reflector so that the wire lay along a focal line (fig. 5).

The method of using was as follows: The iron of the detector was first magnetized to saturation by being thrust into a helix in which a current was made to circulate. The detector was then hung so as to connect with its wings, and on placing it in the field of an electric oscillator, the surgings gathered up by the wings destroyed a portion of the magnetization of the iron. The change in the magnetization was observed in a magnetometer.

* I had forgotten Hertz's experience. See Electric Waves, pp. 172, 175.

† Phil. Trans., A 1897, vol. 189, pp. 1–24.

A section of the magnetometer is shown at M in fig. 8. It was of the plainest construction, consisting simply of a mirror 10^{mm} in diameter with two small steel magnets fastened on the back by paraffine, and suspended by a silk fiber about 12^{cms} long. Behind it was a block B, in which a small glass tube, closed at one end, was wedged. The inner diameter of this tube was approximately equal to the outer diameter of the detector



tube, so that the latter moved snugly into the former, and, when pushed in as far as it would go, was in a definite position which could easily be recovered.

The block B was fastened on the upper face of a board N by a screw *a* around which it could be given a slow motion by a screw S, thus easily making the detector approach or recede from the magnetometer by a small amount. The telescope and scale A were about 120^{cms} from the magnetometer.

The position of the magnetometer was adjusted so that when the detector, fully saturated, was pushed into the tube T, the magnetometer deflection was 40^{cms}, the scale being numbered so that this read zero. After partial demagnetization through the electrical oscillations, it was replaced in its position behind the magnetometer and the alteration in reading observed directly.

It was found that the detector could be removed and replaced with no observable difference in the reading; and successive magnetizations to saturation produced the same deflection.

Rutherford* showed that the demagnetization produced by rapid oscillations is confined to the outer layers of the magnet. The diffusion of the magnetic force from the dielectric into a magnetizable substance is, indeed, similar to the passage of electrical action into a conductor. Hence for rapidly alternating currents the magnetic action is confined to the outer layers, the more rapid the alternation the thinner the layer affected. Hence the reason for using fine wire and insulating the pieces from each other. By so doing more surface is pre-

* Loc. cit.

sented to the dielectric and the effect is greater. In some of his detectors Rutherford used iron wire $0{\cdot}07^{mm}$ in diameter, (i. e., only one-half the diameter of mine), with 160 turns of fine wire on the helix, and much longer wings. Thus he was able to obtain noticeable effects at a distance of over half a mile from the oscillator, which consisted of large plates. My detector, however, was sensitive enough for my purpose.

In the report* on Hertzian Oscillations presented by Righi to the International Congress of Physicists in Paris in 1900, he enumerated 21 kinds of apparatus for indicating the presence of electric oscillations. Of these the magnetic detector is one of the easiest to manage and possibly the simplest for quantitative comparisons, though I know of few investigations in which it has been used.† Its sensitiveness increases as the wings are lengthened, and the greatest difficulty I experienced arose from the fact that it is especially sensitive to the surgings in the connecting wires of the oscillator. An illustration may be interesting.

A wire three meters long was stretched from one terminal of the secondary of an induction coil across to the side of the room, and sparks were made to pass between the ordinary pointed terminals of the coil. The coil was in the basement of the laboratory. A fully magnetized detector, with wings each about 90^{cms} long arranged parallel to the wire running out from the coil, was placed in position by the magnetometer, giving the usual deflection of 40^{cms}. The magnetometer was in a room on the next floor above, and was distant about 35 meters, with brick walls, numberless wires and other pieces of metal between; and yet, as soon as sparks began to pass at the coil the magnetometer deflection was reduced by 2^{cms}.

The detector was also used to determine the wave-length of the oscillators used. The wave-length for the cylinders was found to be approximately 80^{cms}; that for the 10^{cm} spheres, approximately $38{\cdot}5^{cms}$, i. e. 3·85 times the diameter. An account of these experiments will be published later. Using these results the frequencies given in Table I were obtained.

4. *Experiments on the "skin"-effect.*

During the study of the "skin"-effect cylindrical oscillators with the dimensions given above were made as follows:—

No. 1. Solid brass.
No. 2. Solid Norway iron.

* Rapports présentés au congres international de Physique réuni à Paris en 1900. Tome 2, p. 301 (Paris, 1900).

† In the June (1901) Phil. Mag. is a paper by C. G. Barkla. in which are described experiments on the relative velocities of electromagnetic disturbances along wires of different diameters, in which the magnetic detector was used as an indicator.

No. 3 and No. 4. Copper $1{\cdot}5^{mm}$ and $0{\cdot}8^{mm}$ thick, respectively. The mantle was of copper tubing and the hemispherical ends were spun and then soldered on.

No. 5. Solid electric-light carbon.

No. 6. Sheet platinum, over a wooden form. The mantle was $0{\cdot}0013^{cms}$ thick; the hemispherical ends, which were soldered on, were $0{\cdot}015^{cms}$ thick.

No. 7. Sheet silver. Mantle, $0{\cdot}002^{cms}$; ends, $0{\cdot}014^{cms}$.

No. 8. Tin foil, $0{\cdot}0025^{cms}$ thick, on a wooden form.

No. 9. Gold leaf laid upon a wooden form. According to manufacturer, the leaf was about 1/220,000 inch, or $0{\cdot}0000114^{cms}$, thick.

No. 10. Silver leaf laid upon wood. Thickness about $0{\cdot}00003^{cms}$.

Upon cylinders covered with gold leaf copper was deposited electrolytically, the thickness of the copper being in No. 11, No. 12, No. 13, No. 14, No. 15, respectively, $0{\cdot}0001$, $0{\cdot}00015$, $0{\cdot}0002$, $0{\cdot}0003$, $0{\cdot}0005^{cms}$.

No. 16. Silver deposited chemically on glass blown to the proper shape. The thickness, obtained by weighing, was approximately $0{\cdot}000013^{cms}$.

In order to have the ends between which the sparks were to pass as nearly alike as possible these ends were faced with sheet platinum of a thickness $0{\cdot}003^{cms}$. By means of a die discs of 1^{cm} diameter were punched from the sheet. In the case of cylinders No. 1 to No. 4 these discs, after being given the proper spherical curvature, were soldered directly on the cylinder, after which the surplus solder was removed and the platinum polished by a buffing-wheel.

In the case of No. 5, copper was first deposited on the end, and a cap with curvature rather greater than that of the end face was cemented on with shellac. To do this a small piece of shellac was placed on the end and the cap placed in position over it. The shellac was melted by holding a hot wire on the cap, which was then pressed by the finger firmly against the end until the shellac hardened. In this way excellent contact was made all about the circumference of the cap.

No. 6 had excellent platinum faces already, and No. 7 was left without them. On all the rest caps were fastened as on No. 5, i. e., directly cemented with shellac.

Later on, some of the caps were secured in place by holding them firmly against the end of the cylinder and then depositing copper on the edge of the cap and on the cylinder where it rested. This certainly insured perfect electrical connection, and is superior to the cementing method, being more durable, but the results obtained were not noticeably better.

By referring to Table I, it will be seen that for every frequency mentioned there gold and silver leaf are decidedly thinner than the "skin" as there given; while, in the case of the lowest frequency (that of the cylinders), beside the gold and the silver leaf, the metallic portion of cylinders numbered 11, 12, 13, 14 and 16 was thinner than the calculated "skin." One would expect, therefore, that if the efficiency of the oscillator depends on the thickness of the metal constituting it, that dependence would manifest itself in the use of these cylinders; but extended and careful observation failed to detect any evidence whatsoever of such an effect.

The manner of experimenting was as follows: The cylinders were placed in position in the zinc reflector, and the connections and sparking-distance carefully adjusted. Then the magnetized detector was hung in the other reflector, which was placed directly before the first reflector with a certain distance (usually 30^{cms} at first) between the focal lines of the two. The key was then depressed while the pendulum made ten swings, after which the detector was placed in its pocket behind the magnetometer and the change noted in the scale reading. The detector was then magnetized again and the same work performed with the mirrors at a greater distance apart. This was continued until readings at a sufficient number of distances had been secured. Then another pair of cylinders was taken and a similar set of readings obtained.

Rutherford reported that in his experiments no difference could be detected whether the first semi-oscillation in the receiver tended to magnetize the core or the reverse, but in my experiments this was very evident. For instance, on putting the detector in place at 30^{cms} from the oscillator, a scale reading of 57^{mm} was obtained. Next, after re-magnetizing, the detector was hung up so that the face presented to the oscillator was the reverse of that in the former case; in other words, if the detector were now raised out of its mercury cups, turned through 180° about its axis and then dropped into its cups again, its first position would have been recovered. With the detector in this second position a deflection of but 37^{mm} was obtained. The oscillator is very dead-beat, and with the detector in the first position, the first (and greatest) pulse received by it was in the direction to demagnetize the core; in the second position this first pulse was in the opposite direction in the helix, and the total resulting demagnetization was not so great. This difference in reading gradually diminished as the detector was withdrawn from the oscillator, and at about 60^{cms} it disappeared. In Table III is given a series of readings at distances between 30 and 90^{cms}, the two positions of the detector being denoted by 1 and 2.

TABLE III.

Distance of Oscillator from Detector.	Oscillator; position of detector; and scale reading in mm.							
	No. 1.		No. 9.		No. 11.		No. 13.	
cms.	1	2	1	2	1	2	1	2
30	50	25	57	39	50	30	63	48
40	30	22	47	31	34	24	50	41
50	27	26	35	35	30	24	44	38
60	27	25	36	32	29	32	44	43
70	23	22	28	28	25	29	--	--
80	22	20	31	25	27	26	35	35
90	20	20	29	26	25	27	--	--

It would naturally be suspected that this reversal effect was due to the direct action of the coil or of the connecting wires; but on removing the cylinders and substituting therefor small knobs no effect was obtained. Indeed the wings of the detector were made at right angles to the wires leading from the coil to the oscillator in order to avoid such action. Moreover, if it were due to the direct action, the effect would have been more pronounced with the spherical oscillators, but such was not the case.

The readings in the table show irregularity in the action of the oscillators, though I believe it is not so great as in many experiments with electric waves, a fact due largely to the constancy of the interrupter used.

In Table IV readings obtained with various cylinders are exhibited. Each reading is the mean of the two readings obtained, at the distance indicated, by the detector in its two positions. An examination of the results will lead to the conclusion that, for frequencies as high as those here used, the effectiveness of an oscillator is not impaired by using a thin shell instead of a solid.

As stated above, the platinum caps were soldered to the iron and brass cylinders, and were then given an excellent polish. The caps on the gold-leaf and other delicate shells could not be polished in this way. They were simply rubbed clean with chamois. One would naturally expect, therefore, that the solid cylinders would perform best, but such was not the case. Indeed the brass and iron oscillators were the hardest to adjust and seemed about the *least* effective; and the gold-leaf acted so continuously better than the solid that I began to think its thinness was a determining factor. The average of the readings for gold-leaf given in the table is decidedly better than

for the brass oscillator, and numerous other readings accentuated this result. Afterwards, however, the platinum shell (No. 6) was constructed, and proved the most reliable and efficient of all. Now this shell was thicker than the calculated "skin" (Table I), and further, on wrapping two layers of heavy

TABLE IV.

Distance of Oscillator from Detector. cms.	No. of Oscillator; scale-reading in mm.													
	No. 1.	No. 2.	No. 5.	No. 6.	No. 7.	No. 8.	No. 9.	No. 10.	No. 11.	No. 12.	No. 13.	No. 14	No. 15.	No. 16.
30...	37	46	47	46	37	39	39	52	40	48	49	46	57	44
	47	26	49	69	45		58		42		55		46	34
	49			54			47							
40...	22	40	28	38	..	33	30	40	28	34	37	43	45	38
	26			51			39		33		46			
	29						40							
50...	26	28	28	37	..	32	26	35	27	30	47	37	41	37
	30	17	30	44			35		32		41		29	
	30			35			38							
60...	20	26	32	39	35	30	19	33	30	32	41	40	40	27
	26			47			34		31		43		26	27
	28													
70...	18	..	25	..	..	32	19	28	27	28	31	26	36	29
	22						28							
80...	16	21	25	33	22	30	18	26	27	25	26	31	30	..
	21	12		35			38		23		35		22	
	20						29							
90...	20	..	24	..	..	29	27	25	26	21	23	27	29	..
100...	18	..	18	25	..	26	23	21	26	19	21	22	28	..
	22		23	26			24							
120...	13	17	12	22	..	20	14	19	22	15	18	19	25	..
	15	10		23			23		19		26		15	
140...	11	..	..	19	..	15	11	14	17	13	15	15	17	..
	10		15	18			17							
160...	12	12	8	12	..	17	14	14	14	13	12	18	13	..
	10	8		17			21		12		19		10	
180...	12	..	7	..	..	12	11	11	12	9	12	12	14	..
200...	8	5	6	11	..	11	10	10	11	6	10	12	10	..
			11	12					12					

tin-foil (thickness 0·005^{cms}) about the mantle and binding it closely there, no alteration whatever was made in its efficiency. The proper conclusion, therefore, seemed to be that, within the limits of the experiments, the thickness of the metal had no effect.

If one could obtain a thin continuous carbon shell, possibly more decisive experiments might be made, as the "skin" for carbon is comparatively thick, but such was not available.

The magnetic nature of the iron made no difference whatever; iron and brass were indistinguishable in their behavior. Silver did not appear equal to platinum as a spark-surface.

As the experiments with cylindrical shells failed to exhibit any trace of the "skin"-effect, it was decided to try with spheres, and Righi oscillators with spheres 2·5, 4, and 10^{cms}, respectively, in diameter were constructed. By these solid brass spheres were compared with gold-leaf spherical shells of the same diameter. The latter were made by covering with gold-leaf accurately turned and beautifully polished lignum-vitae spheres of the required sizes.

TABLE V.

Spheres 2·5^{cms} in Diameter.

Distance of Oscillator from Detector.	Detector position; and scale readings in mm.								Mean.
	I		II		III		IV		
cms.	1	2	1	2	1	2	1	2	
			1.	Solid					
30	40	44	41	40	46	39	46	35	41·4
50	27	23	24	23	18	20	25	25	23·1
100	15	13	12	8	11	10	12	13	11·8
140	10	7	9	7	8	8	11	7	8·4
200	7	7	7	4	7	4	10	5	6·4
250	7	5	6	5	5	7	8	6	6·1
300	7	6	5	4	4	5	4	5	5·0
			2.	Shell.					
30	39	40	46	37	40	41	50	45	42·3
50	18	22	20	16	22	24	27	28	22·1
100	10	12	10	12	13	13	16	15	12·6
140	8	7	8	7	8	7	12	12	8·6
200	6	4	6	5	5	5	15	9	6·9
250	6	6	6	4	7	5	10	11	6·9
300	5	7	5	7	4	3	10	8	6·1

In the oscillators composed of solid spheres the brass surface was used as sparking faces. Observation showed that, in air, newly polished brass is at least equal and possibly superior to sheet platinum, and the oil dielectric prevents the rapid deterioration of the surface.

For the gold-leaf shells platinum faces were necessary. Two

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were fastened on each sphere, at the extremities of a diameter, by electro-deposition of copper.

The results obtained with the three oscillators are given in Tables V, VI and VII, which explain themselves. With the

TABLE VI.

Spheres 4^{cms} in Diameter.

Distance of Oscillator from Detector. cms.	Detector position; and scale readings in mm.								Mean.
	I		II		III		IV		
	1	2	1	2	1	2	1	2	
			1.	Solid.					
30	73	64	--	60	65	56	68	50	62·3
50	33	--	46	40	30	43	32	30	36·3
100	26	28	20	18	16	17	14	10	18·6
140	18	15	12	10	10	10	7	10	11·5
200	8	8	--	9	--	--	5	4	6·8
250	8	9	9	7	7	6	4	--	7·1
300	6	5	7	5	5	5	3	2	4·8
			2.	Shell.					
30	70	43	74	60	66	48	60	51	59·0
50	32	31	40	36	28	33	33	33	33·3
100	15	14	15	16	14	15	18	16	15·4
140	7	9	15	11	10	13	11	11	10·9
200	10	9	10	6	5	9	7	7	7·9
250	8	10	8	8	6	--	6	8	7·7
300	7	7	12	7	--	--	5	4	7·0

solid spheres the first reading was usually the highest, but with the shells there were usually two or three indifferent ones to start with. This was observed with platinum faces generally. The readings recorded are: for the solid spheres, the first 8 taken; for the 4^{cm} shells, the first 8; for the 2·5^{cm} shells, the last 8 of a series of 14; and for the 10^{cm} shells, all the satisfactory readings obtained.

The 4^{cm} spheres seem to show evidence, at the distance of 30^{cms}, of the reversal effect mentioned above, but it disappeared before a distance of 50^{cms} was reached. With the other spheres no trace of the phenomenon can be found.

No difficulty at all was experienced in handling the smaller spheres, but the larger ones gave some trouble. But a single reading had been secured with the first pair of 10^{cm} shells

before one of them failed. Veins appeared in the gold-leaf encircling one platinum cap. On replacing this sphere by a new one only three or four readings were secured before the other sphere of the first pair failed in the same way. This was removed and a new one put in its place, and with the pair thus formed the readings in Table VII were obtained.

TABLE VII.

Spheres 10^{cms} in Diameter.

Distance of Oscillator from Detector.	Detector position; and scale reading in mm.								Mean.
	I		II		III		IV		
cms.	1	2	1	2	1	2	1	2	
			1.	Solid.					
50	97	117	120	80	133	78	98	95	102·3
100	81	90	88	104	78	100	66	72	84·9
200	55	57	52	43	47	40	39	45	47·3
300	34	34	37	35	38	35	29	27	33·6
500	13	14	10	10	12	10	10	9	11·0
600	9	11	8	7	6	8	6	7	7·8
700	7	4	6	5	5	3	5	5	5·4
			2.	Shell.					
50	110	92	113	107	136	115	120	85	109·5
100	101	85	73	89	76	80	93	89	85·8
200	45	45	49	44	..	..	..	..	45·8
300	30	34	32	34	..	31	..	..	32·2
500	15	12	..	..	..	..	..	..	13·5
600	7	10	..	..	..	..	..	..	8·5
700	5	6	..	..	..	..	..	..	5·5

If curves be drawn with the mean readings of Tables V, VI and VII as ordinates and the distances from the oscillator as abscissae, the curve for a shell will be found to practically coincide with that for the solid sphere of the same diameter. The experiments, therefore, indicate that, both in the case of the cylindrical and of the spherical doublets, the excessively thin gold-leaf shells were quite as efficient as the solid metal bodies.

This investigation was made in the Jefferson Physical Laboratory, Harvard University; and while under especial obligation to Professor Trowbridge for his never-failing consideration and encouragement, I would express my gratitude to every member of his staff for innumerable kindnesses.

Jefferson Physical Laboratory, Harvard University.

ART. II. — *The Influence of Hydrochloric Acid on the Precipitation of Cuprous Sulphocyanide;* by R. G. VAN NAME.

[Contributions from the Kent Chemical Laboratory of Yale University.—CV.]

IN a previous contribution to this Journal* the writer gave the results of a series of experiments upon the estimation of copper by precipitating and weighing as cuprous sulphocyanide. It was concluded from this work that the process did not lose greatly in accuracy even when quite large amounts of sulphuric or hydrochloric acid were present. In discussing the results obtained, however, no distinction was made, as should have been done, between free acid originally present in the solution and that remaining in the free state after the addition of the precipitants, ammonium bisulphite and ammonium sulphocyanide.

With hydrochloric acid the effect of the bisulphite, as will be shown, is to convert a definite quantity of acid into ammonium chloride, so that by increasing the bisulphite the free acid present when the copper is precipitated may be diminished to any desired extent.

The results obtained by precipitating copper in solutions containing various amounts of hydrochloric acid, weighing as cuprous sulphocyanide, and determining the copper in the filtrate, are given in Table I.

In neutral or faintly acid solutions cuprous sulphocyanide is precipitated in a very finely divided state and often shows a tendency to pass through the filter with the wash water as soon as the latter becomes nearly free from dissolved salts. This may be prevented by washing with a salt solution. For this reason the precipitates were washed with decinormal ammonium sulphocyanide, a medium in which cuprous sulphocyanide is even less soluble than in pure water.

An electrolytically standardized copper sulphate solution of about $\frac{1}{8}$ normal strength was measured out in portions of 50^{cm^3} for the first seven determinations. For the last four, like quantities of approximately $\frac{1}{20}$ normal copper sulphate were taken. The required amount of strong hydrochloric acid of specific gravity 1·17–1·18 was then added, followed, after diluting, by ammonium bisulphite and ammonium sulphocyanide in the order named, the last in measured portions of a standardized decinormal solution. The ammonium bisulphite solution was prepared by saturating aqueous ammonia with sulphur dioxide.

After precipitation the mixture was allowed to stand for

* Vol. x, 451.

TABLE I.

Final volume 200$^{cm^3}$.

	Cu taken. grm.	HCl sp. grav. 1·17–1·18. cm^3.	HNH_4SO_3 sat. sol. cm^3.	NH_4SCN approx. n/10. cm^3.	$Cu_2S_2(CN)_2$ found. grm.	Calc. as Cu. grm.	Error. grm.	Cu in filtrate and NH_4SCN washings. grav. grm.	Cu in filtrate and NH_4SCN washings. color. grm.	Cu in alcohol washings. grav. grm.	Cu in alcohol washings. color. grm.	Total Cu found. grm.
1.	·3163		5	60	·6085	·3180	+·0017					·3180
2.	·3163	2	5	60	·6076	·3176	+·0013	·0001	·00005	·0001	none	·3177
3.	·3163	4	5	60	·6083	·3179	+·0016	·0000	·00006	·0001		·3181
4.	·3163	6	5	60	·6072	·3173	+·0010	·0001	·00015	·0001	·00004	·3175
5.	·3163	8	5	60	·6081	·3178	+·0015	·0002		·0000	·00007	·3181
6.	·3163	8	5	60	·6078	·3177	+·0014	·0003	·0005	·0000	·00009	·3183
7.	·3163	12	5	60	·6069	·3172	+·0009	·0004	·0004	·0002	·00002	·3176
8.	·0793	12	5	120	·1521	·0795	+·0002	·0002	·00018		·00008	·0798
9.	·0793	25	5	120	·1512	·0790	−·0003	·0008	·00054		·00004	·0796
									Cu in filtrate. color. grm.	Cu in NH_4SCN washings. color. grm.	Cu in alcohol washings. color. grm.	
10.	·0793	12	2	120	·1518	·0793	·0000		·00063	·00008	·00005	·0801
11.	·0793	25	2	120	·1495	·0781	−·0012		·00135	·00007	·00008	·0798

forty-eight hours or more before filtering, the final volume being in every case 200$^{cm^3}$.

The precipitates were collected upon asbestos in a perforated platinum crucible, washed thoroughly with a decinormal solution of ammonium sulphocyanide and then with alcohol to remove any excess of the ammonium sulphocyanide, dried at 105° and weighed. It should be mentioned in this connection that no distinct instance of the apparent tendency of cuprous sulphocyanide to increase slightly in weight on prolonged heating at 110°, described in the article before referred to, was noticed during the present investigation.

The tests for copper in the filtrates were made by evaporating the solution with nitric acid to a small bulk, heating in a platinum crucible over a radiator to expel sulphuric acid and decompose interfering substances, dissolving the residue in nitric acid, filtering, electrolyzing and weighing the copper.

As the gravimetric results thus obtained were not sufficiently accurate for small amounts of copper, the copper was also determined by the following colorimetric method.

The electrolytic deposit was dissolved in nitric acid and the solution, contained in a small beaker of about 15$^{cm^3}$ capacity placed against a white background, was neutralized with ammonia and made faintly acid with acetic acid. A dilute solution of potassium ferrocyanide was then added, a few drops at a time, until no further deepening of the brown color was observed. Another beaker of the same size containing the same amount of potassium ferrocyanide was placed beside the first, and after diluting its contents to a like volume a copper sulphate solution containing ·00025 grm. of copper per cubic centimeter was added drop by drop from a pipette graduated to hundredths of a cubic centimeter until the brown color was identical with that in the first beaker. With amounts of copper less than ·0001 grm., this method is correct to within ·00002 grm. Its accuracy, however, naturally grows less as the amount of copper increases. The results obtained by the gravimetric and colorimetric methods appear in the table in adjacent columns.

Small amounts of copper were in nearly every case found in the alcohol washings, due to traces of the precipitate passing through the filter with the alcohol. Although it was difficult to entirely prevent loss in this way, in only a few instances was the quantity thus carried through large enough to cause distinct cloudiness in the filtrate. Water might have been used instead of alcohol to wash out the ammonium sulphocyanide, but the chances of loss seemed on the whole to be considerably less when alcohol was employed.

The values obtained by the weighing as cuprous sulpho-

cyanide show, with all but the largest amounts of acid, considerable positive errors. On comparing with these the values in the last column, which represent the total amounts of copper found and are obtained by adding to the figures in the sixth column the amounts of copper in the filtrates and washings as determined by the comparative method, it appears that the positive errors persist throughout. This seems to be due to the method of washing, which apparently fails to remove all the soluble impurities present, for in a number of cases where water alone was used to wash precipitates obtained from these same solutions the results were close to the theory. The use of this method of washing is however justified in this case because it reduces the chances of mechanical loss to a minimum, and accuracy in determining the amounts of copper precipitated is for the present purpose less desirable than accuracy in estimating the amounts remaining in solution.

In the first seven determinations the ammonium bisulphite and sulphocyanide were kept constant and the hydrochloric acid gradually increased. The effect is shown by the weights of copper in the filtrate, which rise fairly steadily to ·0005 grm. with the largest amounts of acid. A part of the hydrochloric acid, however, as already stated, reacts with the bisulphite forming ammonium chloride and liberating sulphur dioxide, and a similar reaction probably takes place with the ammonium sulphocyanide. As hydrochloric acid has a far greater solvent effect upon cuprous sulphocyanide than the equivalent amount of ammonium chloride, the result in both cases would be to diminish the amount of copper held in solution, unless, as hardly seems probable, the sulphur dioxide or sulphocyanic acid liberated is more active in holding up the copper than the corresponding amount of hydrochloric acid. That the weights of copper held in solution do actually decrease with an increase of either the bisulphite or sulphocyanide is readily proved.

The relation between the bisulphite and hydrochloric acid is apparent upon comparing the amounts of copper in the filtrates of the last four determinations of the table. The conditions under which Nos. 8 and 9 were made were respectively the same as those for Nos. 10 and 11 except that the quantity of bisulphite solution used was 5^{cm^3} for the first pair and 2^{cm^3} for the second. The losses are distinctly greater with the smaller amount.

Increasing the ammonium sulphocyanide while the bisulphite and hydrochloric acid remain constant has a similar effect. For the first seven experiments of the table the amount of ammonium sulphocyanide theoretically required was about 50^{cm^3} of the decinormal solution. The excess present was therefore about 10^{cm^3} or 0·076 grm. of the dry salt. In Nos. 8

and 9 the theory required about 13^{cm^3} of the decinormal solution, and the excess was consequently 107^{cm^3} or 0·815 grm. Making due allowance for the large amounts of acid present in these two experiments, the losses are much less than in the preceding ones.

As the reaction between the bisulphite and hydrochloric acid gives rise to a gaseous product (sulphur dioxide), it would naturally be expected that equilibrium would only be reached when one or the other of the reagents was nearly exhausted. If this is true, the measure of the amount of hydrochloric acid which can be converted into ammonium chloride by a definite quantity of bisulphite solution is the weight of combined ammonia which the latter contains. This value was found to be 0·1757 grm. per cubic centimeter for the bisulphite solution used in the above experiments. This means that if equal quantities of the bisulphite solution and of hydrochloric acid of sp. grav. 1·18 act upon one another, nearly nine-tenths of the acid may be converted into ammonium chloride. It is, however, not necessary to assume that this reaction is complete under the conditions of the experiments of the table. If with a given amount of hydrochloric acid it progresses farther when the quantity of bisulphite is increased, the results are sufficiently explained.

The limit of the reaction between the ammonium sulphocyanide and hydrochloric acid is entirely indefinite, but an increase in the amount of this salt must, as in the case of the bisulphite, cause the neutralization of a greater amount of acid and thus bring about a more complete precipitation of the copper. Very probably, the reduction in the solubility of the precipitate in the acid solution caused by the presence of an excess of ammonium sulphocyanide,* also contributes to this effect.

From these results it is evident that even in strongly acid solutions the copper may be almost completely precipitated by sufficiently increasing the amounts of ammonium bisulphite and sulphocyanide. As far as could be judged from a limited number of determinations made in sulphuric acid solution, the above holds true for sulphuric as well as hydrochloric acid. Cuprous sulphocyanide is, however, somewhat soluble in solutions of ammonium salts, and in cases where the amount of acid is very large this may become an important factor.

The solubility of cuprous sulphocyanide in various solutions is shown in the following table, but the figures must be understood to be only approximate. Weighed amounts of cuprous sulphocyanide prepared by precipitation in the usual way,

* See Table II.

thoroughly washed, and dried at 105°, were allowed to stand in the solutions to be tested from 40 to 50 hours. After careful filtering through asbestos the copper in the clear filtrate was estimated by the battery or, in cases where the amount was small, by the colorimetric method described above.

TABLE II.

Volume of liquid, 200^{cm3}.

$Cu_2S_2(CN)_2$ taken. grm.	HCl sp. grav., 1·18 cm^3.	NH_4SCN grm.	Cu in filtrate. grm.
0·3			0·00035
0·3			0·00040
0·3		10·	0 0050
0·25		1·52 $\left(\frac{n}{10}\right)$	0·00018
0·3		0·76 $\left(\frac{n}{20}\right)$	0·00007
0·3		0·19 $\left(\frac{n}{80}\right)$	0·00004
0·3	2		0·0019
0·3	2	2·5	0·0013
0·3	2	1·77*	0·0009
0·3	2	0·19	0·0006
	NH_4Cl grm.		
0·3	10		0·0031
0·3	10	0·19	0·00013
0·3	1 $\left(\frac{n}{10}\right)$†		0·00045
0·3	1	0·19	0·00005

The solubility is lowest in dilute solutions of ammonium sulphocyanide, and the presence of a small amount of this salt lessens the solubility in hydrochloric acid, and in solutions of ammonium chloride. In decinormal ammonium chloride the solubility is greater than in ammonium sulphocyanide of like strength, but this order is reversed in more concentrated solutions.

The results of the investigation may be summarized as follows: In the presence of free‡ hydrochloric acid the precipitation of cuprous sulphocyanide by a small excess of ammonium sulphocyanide is incomplete, but not injuriously so unless the

* Equivalent to the amount of hydrochloric acid present.

† Approximately.

‡ By free acid is here to be understood that acid which remains in the free state after the interaction with the ammonium bisulphite.

amount of the concentrated acid exceeds about 0·5 per cent of the total volume. By employing a considerable excess of ammonium sulphocyanide the precipitation can be made practically complete, at least after a few hours standing, even when the amount of acid is several times the above figure. The use of a decided excess of the sulphocyanide is advisable not only in the presence of acid but also when the solution contains much ammonium salts, on account of the reduction in the solubility of the precipitate thus brought about.*

The result of an increase in the ammonium bisulphite in the presence of hydrochloric acid is, except for the liberation of sulphur dioxide, exactly the same as the effect produced by a partial neutralization of the acid by ammonia, namely, the formation of ammonium chloride at the expense of the acid. Unless the amount of acid thus neutralized is quite large, the solubility of the cuprous sulphocyanide in the ammonium salts formed is too small to interfere materially with the completeness of the precipitation. There is, moreover, no objection to the use of ammonia in addition to the bisulphite to neutralize an excess of acid, and where sulphur dioxide is employed in place of ammonium bisulphite, ammonia is in many cases desirable. If, finally, the amount of acid is very large it is unquestionably better to remove the greater part before precipitating the copper.

The helpful advice of Prof. F. A. Gooch throughout the course of this investigation is gratefully acknowledged.

* See the last four determinations of Table II.

ART. III.—*The Action of Ammonium Chloride upon certain Silicates;* by F. W. CLARKE and GEORGE STEIGER.

IN our previous communications* upon the ammonium chloride reaction, we have shown that different silicates are very differently affected by the reagent. From analcite, leucite, natrolite and scolecite we obtained new salts, in which the alkali or lime of the original mineral had been replaced by ammonium. On the other hand, prehnite was practically unattacked, while the pectolite molecule was quite thoroughly broken down, with liberation of much free silica. We now submit the results obtained with several additional silicates; results which serve to emphasize our former conclusions.

Our mode of operation has been precisely the same as before. Each mineral, in fine powder, was intimately mixed with four times its weight of dry ammonium chloride, and the mixture was then heated for about five or six hours to 350° in a sealed combustion tube. After cooling, the mixture was leached out with water, and the air-dried insoluble residue was analyzed. Determinations of free silica were effected by boiling the mineral, or its derivative, for fifteen minutes with a solution of sodium carbonate containing 250 grams to the liter. From the solution so obtained the silica was recovered by acidulation with hydrochloric acid and evaporation to dryness. In each case all of the experiments were made upon one uniform sample of material, so that the data for any one species are strictly comparable. So much premised, we may go on to consider the results of our investigations.

Stilbite.

The specimen selected for study was a nearly white, typical example from Wasson's Bluff, Nova Scotia. The analysis and the fractional water determinations were as follows:

	Analysis.		Fractional water.
SiO_2	55·41	At 100°	3·60
Al_2O_3	16·85	" 180°	6·46
Fe_2O_3	·18	" 250°	3·80
MgO	·05	" 350°	2·10
CaO	7·78	Low redness	2·95
Na_2O	1·23	Full "	·06
H_2O	19·01	Over blast	·04
	100·51		19·01

* This Journal (4), ix, pp. 117, 345; February and May, 1900.

On boiling with sodium carbonate, 1·37 per cent of silica went into solution. After ignition, only 1·03 per cent was obtained. No silica, therefore, is split off when stilbite is ignited. If the mineral were a hydrous acid metasilicate, $H_4CaAl_2Si_6O_{16} \cdot 4H_2O$, as has been assumed by some authorities, one-third of the silica should have been set free. Hence the metasilicate formula is to be regarded as unsatisfactory. The evidence here presented counts for something against it.

Two samples of the ammonium chloride derivative were prepared. In leaching with water the insoluble residue was washed until the washings gave no reaction for chlorine. The chlorine shown in the subjoined analyses is, therefore, present in an insoluble form, and not as adhering ammonium chloride. Dried at 50°, the two products gave the following composition:

	A	B
SiO_2	60·80	60·67
Al_2O_3	18·36	18·25
CaO	1·86	1·46
Na_2O	·08	·15
NH_3	5·12	5·13
H_2O	12·96	13·91
Cl	1·31	1·04
	100·49	100·61
Less O	·29	·23
	100·20	100·38

Sample B was further examined as to the presence of soluble silica, and 1·52 per cent was found. After ignition, only 1·62 per cent went into solution. These results conform to those obtained with the original stilbite, and tend to show that the ammonium derivative is a compound of the same order. In the case of the unignited substance the residue remaining after the removal of soluble silica was thoroughly washed, and then examined for alkali. It was found to contain 9·30 per cent of soda, which shows that the ammonium salt had been transformed back into the corresponding sodium compound.

From the foregoing facts it is clear that stilbite, like the zeolites previously studied, is converted by the action of ammonium chloride into an ammonium salt. That is, sodium and calcium are removed as chlorides, ammonium taking their place to form ammonium-stilbite. The reaction, however, is less complete than it was in the cases of analcite and natrolite, but whether this is due to a greater stability of the stilbite molecule, or only to a different degree of fineness in the powder upon which the operations were performed, we cannot

say. Neither have we any explanation to offer of the retention of chlorine by the ammonium derivative. Although the amount of chlorine is small, it needs to be accounted for.

If we discuss the composition of the stilbite and of its ammonium derivative, the relations between them become very clear. Neglecting the water as "zeolitic," to use Friedel's phrase, and, therefore, as not a part of the chemical molecule, and also rejecting the 1·37 per cent of soluble silica as probably an impurity, the ratios derived from the analysis give this empirical formula for the mineral:

$$Na_{40}Ca_{140}Al_{322}Si_{901}O_{2469}.$$

This corresponds to a mixture of ortho- and trisilicates in which $Si_3O_8 : SiO_4 :: 286 : 43$; and uniting these radicles under the indiscriminate symbol X, we have, as a more general expression,

$$Na_{40}Ca_{140}Al_{322}X_{886};$$

or, combining monoxide bases,

$$R''_{180}Al_{322}X_{886},$$

which is essentially $R''Al_2X_5$. Since the SiO_4 groups are practically equal in number to the sodium atoms, the stilbite is probably a mixture, very nearly, of $NaAlSiO_4$ and $CaAl_2(Si_2O_8)_2$ in the ratio of one to seven. This is in accordance with the well-known theory of Fresenius as to the constitution of the phillipsite group, to which stilbite belongs. Stilbite is mainly a hydrous calcium albite, commingled with varying amounts of corresponding orthosilicates of soda and lime.

For the ammonium derivative similar relations hold. Taking analysis "B" for discussion, rejecting soluble silica and chlorine as impurities, and neglecting all water except that which belongs to the supposable ammonium oxide, the ratios give this formula:

$$(NH_4)_{301}Na_4Ca_{28}Al_{322}Si_{925}O_{2288}.$$

Uniting sodium and calcium with ammonium this becomes

$$R'_{337}Al_{322}(Si_2O_5)_{114}(SiO_4)_{43};$$

or, more generally,

$$R'_{337}Al_{322}X_{901} = 1 : 1 : 1.$$

The derivative, therefore, is a compound of the same order as the original stilbite, with the ratio of 1 : 7 still holding between the ortho- and trisilicate groups. This conclusion, however, ignores the presence of chlorine, and is, therefore, inexact to some extent. We are not dealing with ideally pure compounds.

Heulandite.

Pure, white heulandite from Berufiörd, Iceland, was the material taken for investigation. Upon boiling with sodium carbonate, 1·73 per cent of silica went into solution. From previously ignited heulandite only 1·14 per cent was extracted. No silica, therefore, was liberated upon ignition, and a hydrous metasilicate formula for the mineral seems to be improbable. Only one lot of the ammonium chloride derivative was prepared, and its composition, together with that of the heulandite, is given below.

	Heulandite.	Ammonium salt.
SiO_2	57·10	61·24
Al_2O_3	16·82	18·00
MgO	·07	----
CaO	6·95	2·56
SrO	·46	----
Na_2O	1·25	·60
K_2O	·42	
NH_3	----	4·42
H_2O at 100°	3·61	13·63
H_2O above 100°	13·00	
	99·68	100·45

Here again we have the same kind of transformation as before, but rather less complete than in the case of stilbite. That the ammonium taken up is equivalent to the bases removed, is shown by a study of the ratios. Ignoring water and the soluble silica, the heulandite ratios are as follows:

$$R'_{45}R''_{130}Al_{320}Si_{939}O_{2496},$$

or, uniting bases,

$$R''_{184}Al_{320}(Si_2O_5)_{200}(SiO_4)_{24}.$$

Again simplifying, this becomes

$$R''_{184}Al_{320}X_{924},$$

or very nearly 1 : 2 : 2, as in stilbite.

Similarly discussed, the ammonium salt gives the ratios

$$R'_{270}Ca_{46}Al_{252}Si_{1021}O_{2746},$$

equivalent to

$$R'_{362}Al_{362}X_{362}, \text{ or } 1:1:1.$$

In both cases the orthosilicate molecules are few, and the compounds approximate to trisilicates very closely.

Chabazite.

Characteristic flesh-colored crystals from Wasson's Bluff, Nova Scotia. The analysis and fractional water determinations are as follows:

	Analysis.	Fractional water.	
SiO_2	50·78	At 100°	5·22
Al_2O_3	17·18	" 180°	5·70
Fe_2O_3	·40	" 250°	3·92
MgO	·04	" 350°	2·36
CaO	7·84	Low redness	4·51
Na_2O	1·28	Full redness	·13
K_2O	·73	Over blast	·01
H_2O	21·85		21·85
	100·10		

The unignited mineral, upon boiling with sodium carbonate, gave 0·86 per cent of soluble silica. After ignition only 0·53 per cent was soluble. Here again no silica is liberated by calcination, and metasilicate formulæ may be disregarded.

Two samples of the ammonium chloride derivative were prepared, which after thorough washing were dried at 40° to 50°. As in the case of stilbite, small quantities of chlorine appear in the compound, not removable by washing. The amount of change effected is also somewhat less than with stilbite, and about the same as with heulandite. The analyses of the two samples are subjoined, with the remaining alkali all reckoned as soda.

	A	B
SiO_2	55·88	56·09
Al_2O_3	19·15	19·49
CaO	2·25	2·01
$Na_2O(K_2O)$	·35	·24
NH_3	4·64	4·83
H_2O	16·57	16·01
Cl	·95	1·35
	99·79	100·02
Less O	·21	·30
	99·58	99·72

In B, 1·50 per cent of soluble silica was found. After ignition, this was reduced to 1·12 per cent. No liberation of silica accompanies the splitting off of water and ammonia.

Upon studying the molecular ratios for chabazite and its derivative, relations appear precisely like those found for stilbite and heulandite. For chabazite itself, rejecting water and the 0·86 per cent of soluble silica, we have

$$R'_{60}Ca_{141}Al_{340}Si_{822}O_{2244},$$

or, consolidating soda with lime,

$$Ca_{170}Al_{340}(Si_3O_8)_{240}(SiO_4)_{94}.$$

One step further and this becomes

$$Ca_{170}Al_{340}X_{340}, = 1 : 2 : 2.$$

Treating derivative "B" in the same way, and ignoring chlorine as an unexplained impurity, the analysis gives

$$(NH_4)_{284}Na_8Ca_{33}Al_{369}(Si_2O_5)_{206}(SiO_4)_{112};$$

or, consolidating bases as before,

$$R'_{362}Al_{369}X_{378}, = 1 : 1 : 1 \text{ nearly.}$$

The assumption of commingled ortho- and trisilicate molecules conforms to Streng's theory of the constitution of chabazite.

Thomsonite.

The compact-fibrous variety from Table Mountain, near Golden, Colorado. Analytical data as follows:

	Analysis.	Fractional water.	
SiO_2	41·13	At 100°	1·01
Al_2O_3	29·58	" 180°	1·44
CaO	11·25	" 250°	1·05
Na_2O	5·31	" 350°	3·90
H_2O	13·13	Low redness	5·65
		Over blast	·08
	100·40		13·13

Before ignition the mineral yielded 0·45 per cent of silica to sodium carbonate solution. After ignition, 0·68 per cent was soluble. The difference is trifling.

Two samples of the ammonium chloride derivative were prepared. In "A" the heating was only to 300°, in "B" to 350°. Analyses of the leached products gave the following results:

	A	B
SiO_2	42·41	42·65
Al_2O_3	30·50	31·34
CaO	10·00	9·23
Na_2O	2·63	2·48
NH_3	2·45	2·67
H_2O	11·96	11·81
	99·95	100·18

In "A," 1·80 per cent of soluble silica was found.

In this case the amount of change is very much less than with the zeolites previously examined. Little lime was removed, and only about half of the soda. Both samples were prepared with six hours of heating in the sealed tube, and it

seemed to be desirable to determine whether a more prolonged treatment would produce any greater effect. Accordingly a third lot of thomsonite was mixed with ammonium chloride, and heated in a sealed tube to 350° for 24 hours. The leached product contained 3·40 per cent of ammonia, a distinct increase over the other findings; although the amount of transformation into an ammonium salt was still only moderate.

We have already seen that stilbite, heulandite and chabazite approximate more or less nearly to trisilicates in their composition. Thomsonite, however, is essentially an orthosilicate, with variable admixtures of trisilicate molecules. In the example under consideration, ignoring water and soluble silica, the molecular ratios give this formula:

$$Na_{172}Ca_{201}Al_{830}(Si_3O_8)_{80}(SiO_4)_{328};$$

or, condensing,

$$R''_{387}Al_{830}X_{976}, = 1 : 2 : 2.$$

Here the acid radicles are ten-elevenths orthosilicate. Ammonium derivative "A," similarly computed, gives first—

$$(NH_4)_{144}Na_{84}Ca_{179}Al_{808}(Si_3O_8)_{41}(SiO_4)_{324};$$

or, uniting univalent bases with line,

$$R''_{292}Al_{698}X_{893}, = 1 : 2 : 2;$$

the fundamental ratios being practically unchanged.

It will be observed that in all of these computations of formulæ we have assumed that all the water is "zeolitic"; that is, independent of the true chemical molecules. This question, however, needs to be separately investigated for each individual species. While the assumption is valid for some of these minerals, it is not necessarily valid for all. The real chemical differences between the zeolites are yet to be determined; our work merely proves that ammonium compounds are formed, completely in some cases, partially in others. The research should be extended to cover all the zeolites; but this task we must leave to other investigators. Silicates belonging to quite different groups must now claim our attention.

Ilvaite.

This rare mineral was found by Mr. Waldemar Lindgren at the Golconda Mine, South Mountain, Owyhee County, Idaho. It occurs in jet black masses and occasional rough crystals, imbedded in quartz or calcite, and intimately associated with two other minerals which appear to be garnet and tremolite. Traces of pyrite also appear. The specific gravity of the ilvaite, as determined by Dr. Hillebrand, is 4·059 at 31°.

Upon grinding the powdered mineral with ammonium chloride in an agate mortar, a distinct smell of ammonia was noticeable. Three tubes of the mixture were heated to 350°, and one exploded because of the liberation of gas within. Upon opening the second and third tubes, a strong outrush of ammonia was observed. When the contents of these tubes were leached with water, large quantities of ferrous chloride went into solution; which, rapidly oxidizing, formed a deposit of brownish hydroxide, and interfered seriously with filtration. The greater part of the lime in the ilvaite was dissolved also. The washed residue, containing much ferric hydroxide, was partially analyzed, and enough data were obtained to show that a general breaking down of the ilvaite molecule had been effected. Apparently, also, small quantities of an ammonium derivative had been formed; but this point is uncertain. The original mineral was analyzed by Dr. W. F. Hillebrand; and his analysis, contrasted with that of the leached residue, is given below.

	Ilvaite (Hillebrand).	Residue (Steiger).
SiO_2	29·16	43·01
Al_2O_3	·52	40·08
Fe_2O_3	20·40	
FeO	29·14	8·75
MnO	5·15	·85
CaO	13·02	2·25
MgO	·15	undet.
Na_2O	·08	undet.
NH_3	----	·88
H_2O at 105°	·15	undet.
H_2O above 105°	2·64	undet.
Cl	----	small amount.
	100·41	95·82

In the leached residue from the third tube 21·37 per cent of soluble silica was found; silica which had been liberated during the reaction between the ilvaite and the ammonium chloride. In short, ilvaite behaves towards the reagent much like pectolite, and the product is a mixture of uncertain character. The evident instability of the ilvaite molecule may account for its rarity as a mineral species. Only exceptional conditions would favor its formation.

Riebeckite?

The results obtained with ilvaite made it desirable to study, for comparison, some other silicates of iron. Among these the mineral from St. Peter's Dome, near Pike's Peak, Colo-

rado, originally described by Koenig as arfvedsonite, but identified by Lacroix as near riebeckite, happened to be available. It was treated with ammonium chloride in the usual way, and no presence of liberated gas was noticed when the tube was opened. On leaching the product with water, ferrous chloride went into solution, and ferric hydroxide with some manganic hydroxide were deposited. In the leached mass 6·90 per cent of soluble silica was found, and in the wash water from the leaching there were 6·76 per cent of soda. According to Koenig's analysis the mineral contains 8·33 per cent of soda, so that a large portion of the total amount had been extracted. There was also, evidently, a considerable breaking down of the molecule, but no definite ammonium derivative had been formed. This is shown by the following analysis of the leached residue, which is contrasted with Koenig's published analysis* of the original mineral, in order to indicate the amount of change. In the third column of figures we give the amount of each constituent which could be dissolved out from the residue by treatment with hydrochloric acid.

	Riebeckite (Koenig).	Residue (Steiger).	Soluble portion.
SiO_2	49·83	67·54	
TiO_2	1·43	----	
ZrO_2	·75	----	
Fe_2O_3	14·87	21·28	15·74
FeO	18·86	4·94	4·94
MnO	1·75	·64	·64
MgO	·41	none	
CaO	----	trace	
Na_2O	8·33	1·04	
K_2O	1·44		
NH_3	-- -	·53	·53
H_2O	·20 (ign.)	3·33	
Cl	----	trace	
	97·87	99·30	

The residue is evidently a mixture of free silica and ferric hydrate with probably at least two silicates, one soluble, the other insoluble in hydrochloric acid. The reaction itself is noteworthy because of the fact that the original mineral is but slightly attacked when boiled with strong hydrochloric acid. The other minerals so far studied by us are all easily decomposable by acids, while this one is quite refractory. The energetic character of the ammonium chloride reaction is thus strongly emphasized.

* Dana's System of Mineralogy, 6th ed., p. 400.

Aegirite.

Material from the well known locality at Magnet Cove, Arkansas. Not absolutely pure, but somewhat contaminated by ferric hydroxide. This impurity is evident in a discussion of the ratios furnished by the analysis, but is not serious. It does not affect the problems under consideration. By heating with ammonium chloride the mineral was only slightly changed. In the leach water from the product there were 1·66 per cent $(AlFe)_2O_3$, 0·51 CaO, and 1·18 Na_2O. Analyses as follows: A of the aegirite, B of the air dried, leached residue.

	A	B
SiO_2	50·45	51·83
Al_2O_3	2·76	25·24
Fe_2O_3	23·42	
FeO	5·26	5·69
MnO	·10	----
MgO	1·48	1·58
CaO	5·92	5·74
Na_2O	9·84	9·07
K_2O	·24	
NH_3	----	·26
H_2O at 100°	·15	·90
H_2O above 100°	·40	
	100·02	100·31

Of the silica in the residue 4·42 per cent was soluble in sodium carbonate solution. An ammonium derivative was not formed.

From these data we see that the three iron silicates are very differently attacked by ammonium chloride; ilvaite very strongly, riebeckite moderately, and aegirite but feebly. The aegirite is the most stable, and at the same time the commonest of the three. A comparison of the aegirite analysis with that made by J. Lawrence Smith of material from the same region, shows notable differences. The mineral evidently varies in composition; the variation depending upon the relative amounts of the two silicate molecules $FeNaSi_2O_6$ and $R''SiO_3$. Two samples taken from different parts of the same rock area are not necessarily identical in composition.

Serpentine.

In 1890 Clarke and Schneider published an investigation* relative to the action of gaseous hydrochloric acid upon various minerals. Among these were the three species serpentine,

* Bulletin 78, U. S. Geol. Survey, p. 11.

leuchtenbergite, and phlogopite, and the remainders of the original samples were fortunately at our disposal. The analyses made by Schneider are, therefore, directly comparable with the new data secured by us.

The serpentine, from Newburyport, Massachusetts, was but moderately attacked upon heating with ammonium chloride. Upon leaching the contents of the sealed tube with water, 0·18 per cent of silica and 5·23 of magnesia went into solution. The washed residue and the serpentine had the following composition.

	Serpentine (Schneider).	Residue (Steiger).
SiO_2	41·47	45·42
Fe_2O_3, Al_2O_3	1·73	·88
MgO	41·70	39·54
FeO	·09	----
NH_3	----	·09
H_2O	15·06	14·01
	100·05	99·94

The leached residue contained 1·06 per cent of soluble silica. The amount of change effected in the mineral was evidently small, and no ammonium compound was produced.

Leuchtenbergite.

From the standard locality near Slatoust in the Urals. When the contents of the sealed tube were leached with water, there passed into solution 0·19 per cent of alumina, plus iron, 2·10 of magnesia, and 2·03 of lime. The residue was not completely analyzed, but the few determinations made contrast with Schneider's results as follows:

	Leuchtenbergite.	Residue (Steiger).
SiO_2	32·27	32·82
Al_2O_3	16·05	
Fe_2O_3	4·26	
FeO	·28	
MgO	29·75	
CaO	6·21	4·67
NH_3	----	·25
H_2O	11·47	12·11
	100·29	

No definite ammonium compound was formed, and the amount of decomposition was small. As the lime shown by the analysis is at least partly due to the presence of garnet as an impurity in the mineral, it will be interesting to determine the effect producible by ammonium chloride upon that species.

Phlogopite.

From Burgess, Canada. The contents of the sealed tube, after heating, showed little appearance of change. The leach water contained magnesia. Analysis as follows:

	Phlogopite (Schneider).	Residue (Steiger).
SiO_2	39·66	45·03
TiO_2	·56	----
Al_2O_3	17·00	15·07
Fe_2O_3	·27	
FeO	·20	----
BaO	·62	----
MgO	26·49	24·94
Na_2O	·60	·94
K_2O	9·97	8·69
NH_3	----	·21
H_2O	2·99	5·01
F	2·24	----
	100·60	99·89
Less O	·94	
	99·66	

The residue, on boiling with sodium carbonate, gave 0·40 per cent of soluble silica. From these data it appears that phlogopite is somewhat attacked by ammonium chloride, but not strongly. No ammonium derivative is formed.

As opportunity offers, this investigation will be carried further, and the reaction will be applied to other mineral species.

Laboratory U. S. Geological Survey, Oct. 12, 1901.

ART. IV. — *Studies of Eocene Mammalia in the Marsh Collection, Peabody Museum;* by J. L. WORTMAN.

[Continued from vol. xii, p. 432.]

Mesonyx obtusidens Cope.

Numerous remains of this species are preserved in the present collection, one specimen of which includes many parts of the skeleton. In this one the hind limbs are more or less complete, and, as the Princeton specimen which formed the basis of Professor Scott's excellent memoir on this subject* is more or less lacking in these parts, I give herewith a statement of their principal characters.

The femur is somewhat damaged, but there is evidence to show that it was proportionally longer and much more slender than that of *Dromocyon vorax*. The tibia is also longer and decidedly more slender than that of either *Dromocyon* or the Princeton specimen. As compared with the former it is actually longer, but at least one-third less robust. Scott gives the length of the Princeton specimen as 205^{mm}, while the present specimen measures 222½^{mm}.

The same degree of elongation extends to the pes, figure 61, in which the length greatly exceeds that of *Dromocyon*. The fifth metatarsal, which is the only complete one in the Princeton specimen, is also notably longer. It may well be that the present specimen indicates the existence of another species characterized by the elongation and slenderness of its limbs, which are actually greater in this respect than in the modern Greyhound; but it will perhaps be best to regard it, for the present at least, as an extreme variation of *Mesonyx obtusidens*. I introduce in this connection a drawing of the hind foot of a modern dog (Bloodhound), figure 62, in order to show the comparison.

The principal characters of the foot of *M. obtusidens* may be briefly summarized as follows: The *tuber calcis* is exceptionally long and slender, indicating tremendous leverage power in the extension of the foot; the astragalus is deeply grooved upon its trochlear surface, and the head is not so obliquely placed as in *Dromocyon*. The length of the tarsus considerably exceeds that of the metapodials. The internal cuneiform is long and narrow, with a very small facet for the rudimental first metatarsal; the second and third metatarsals are of equal length and size; the fifth is shorter than the second, which is the stoutest bone of the series; the metatarsals are highly compressed and interlocking; the distal ends have a distinctly canine appearance, and the keels are confined

* Jour. Acad. Nat. Sci. Phila., 1886.

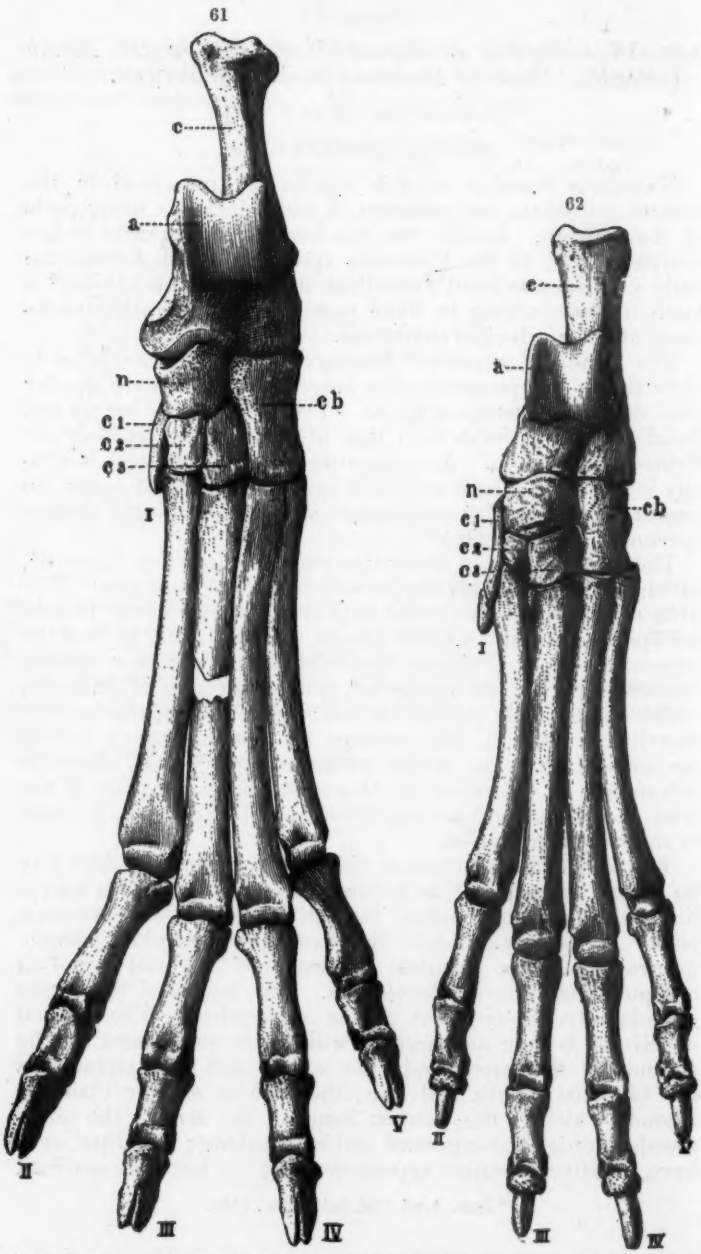

FIGURE 61.—Left hind foot of *Mesonyx obtusidens* Cope; anterior view; three-fourths natural size.

FIGURE 62.—Left hind foot of a dog (Bloodhound); anterior view; about three-fourths natural size.

Lettering as in Plate VIII.

to the plantar surfaces; the phalanges are long and slender, and the bony claws are rather narrow and deeply fissured. The measurements are as follows:

Length of tibia	222·5mm
Length of foot	236·
Length of tarsus	89·
Length of third metatarsal	87·
Length of fifth metatarsal	76·
Length of second metatarsal	79·
Length of first phalanx, digit II	33·
Length of first phalanx, digit III	32·
Length of first phalanx, digit V	27·
Length of second phalanx, digit III	17·
Length of ungual phalanx, digit III	18·

Discussion.—Attention has already been drawn to the fact that the phylogenetic history of this subfamily is unusually complete, from the time when we first meet with it in the Torrejon Beds, up to the time of its final extinction at the close of the Eocene. Although the representatives of the last, or Uinta, stage, are not fully known, there are very good reasons for the belief that *Mesonyx* represents essentially as high a degree of perfection as the group attained. The amount of change in its osteological structure does not, at first sight, appear to be great, yet the gradual modification of the limbs and feet from the short, broad, pentadactyle, plantigrade condition of *Dissacus*, to the elongated, compressed, tetradactyle, highly digitigrade feet of *Mesonyx*, almost if not quite equal to the Greyhound in point of specialization of these characters, is an accomplishment which the modern dogs, with the advantage of a much longer existence, have only comparatively recently achieved.

Origin of the Tritubercular Molar.

The modification of the skull and teeth, while not of so pronounced a character as that of the limbs, is nevertheless very apparent. The molars of the inferior series have gradually lost the internal cusp of the trigon, and the pattern of the crown has, in consequence, assumed a simpler or premolariform structure. It is manifestly improper to say, however, that they underwent any degenerate changes, since at no point in the history of the phylum do they show any disposition or exhibit any tendency to decrease in size or become less functional than in the earliest members. The loss of this cusp is paralleled in many groups of the Carnivora, but in all such cases thus far known its disappearance has been accompanied by the development of a more perfect sectorial structure of the remaining cusps of the trigon. It is more than probable that the loss of this element, which at best is but weakly or imperfectly developed

in *Dissacus*, is to be accounted for on the ground of a better adaptation to the modified structure of the superior molars, which gradually supervened in the course of their development.

The molars and premolars of the superior series exhibit some very distinctive modifications, and as these are in such

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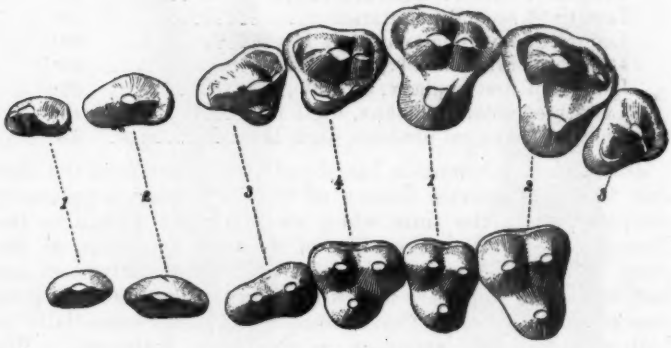

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FIGURE 63.—Left upper teeth of *Dissacus saurognathus* Wortman; crown view; one and one-eighth natural size. (After Osborn.)

FIGURE 64.—Left upper teeth of *Mesonyx obtusidens* Cope; crown view; three-fourths natural size. (After Scott.)

strict accord with what we know has taken place in many other well-established phyletic series wherein greater complexity was attained, we may safely assume that the later condition in this group is the more advanced, specialized, or progressive. In *Dissacus*, figure 63, the first two premolars have simple premolariform crowns, with small posterior heels. The third is of much interest, in that it exhibits a transition from the simple type of tooth crown to the more complex crown of the molars. It is of the *utmost importance* to note that the principal, and, therefore, the primitive cone, or cusp, of the simple stage is located as usual about the middle of the tooth crown, and that the heel has been developed into a small but distinct cusp immediately posterior to it. At the same time an internal cusp has appeared, just internal to, or on the lingual side of, the principal or primitive cusp. The crown of the fourth premolar exhibits the same elements in exactly the same order of arrangement, but somewhat more advanced towards the true molar type. The main cusp has its position apparently changed to a slightly more external one, by reason of the increase in size of the posterior external cusp and the spreading out and enlargement of the internal cusp. A

small posterior intermediate cusp is also developed. The pattern of the crown of the first molar is almost an exact counterpart of that of the fourth premolar, with the exception that the postero-external cusp has undergone still further enlargement, and the internal cusp has increased in size until the tooth crown is now nearly triangular. The anterior cusp of the two externals is still distinctly the larger, and has a position well towards the middle of the outer border. The posterior intermediate cusp is not developed. The second molar is interesting as showing a stage of development intermediate between that of the first molar and the fourth premolar. The internal cusp is much enlarged, but the postero-external is yet small.

Having thus described at some length the first term of the series, let us now turn to the last or final stage, to discover, if possible, just what changes have been effected. It may be added, *en passant*, that every intermediate stage between the two is known, and that, moreover, from strata of intermediate position with respect to the time scale. In *Mesonyx*, figure 64, we observe that very little change has taken place in the first and second premolars. In the third, the internal cusp has disappeared and the posterior has been enlarged. In the fourth premolar the postero-external cusp has increased in size until the two externals are equal, and the internal cusp is enlarged so as to give a perfectly molariform type of crown. The position of the principal or primitive cusp is now more or less at the antero-external angle on account of the increase in the size of the postero-external, as well as the growth of the internal cusp. The crowns of the first and second molars have become fully tritubercular, the two external cusps are of equal dimensions, and are situated more or less exactly at the two external angles. The last molar has completely disappeared.

So much for the facts. Let us next direct attention to their application and general bearing upon the determination of the order of addition and homologies of the respective elements composing the mammalian tritubercular molar crown. I shall purposely limit what I have to say here upon the subject to a consideration of the superior molars, and I shall, moreover, confine my remarks as nearly as possible to the present phylum, for the reason that it offers the best and most direct evidence with which I am acquainted, and by means of which an understanding of some of the primary truths of cusp addition in the true molars of the placental Mammalia can be had. It must be remembered, however, that much evidence of a similar character in other phyletic series whose history is quite as well established is not altogether wanting.

It is and has been assumed, as one of the fundamental principles of this process, that the tritubercular stage of development was preceded by, and was the direct result of, the addition of certain new cusps to a more or less simple elongated conical crown. The evidence in support of this postulate rests not only upon the most excellent and weighty *a priori* reasoning, but is derived from the premolars of any reasonably complete and connected series of forms whose premolars were complicating and whose history can be traced over any considerable length of time. If a single tooth is selected and traced through the various stages of such a series, it will be seen that certain new cusps are added in a more or less definite way. The first step in this advance in structure is usually the addition of a cusp to the posterior border, in the form of a basal talon. The next is an internal cusp which arises from the cingulum, and by gradual enlargement becomes the main internal cusp of the tritubercular crown. It should be noted just here, however, that the exact order of appearance is by no means constant, for it may so happen that the internal cusp has appeared before the posterior, or the two may appear simultaneously. But what is of the *utmost importance* to a proper understanding of the subject, is to note that the *tritubercular crown of every complicated premolar thus far known among the placental mammals has originated by the addition of these two cusps in these situations, leaving in every case the main or primitive cusp at the antero-external angle.* Scott has demonstrated this fact so *fully and conclusively** that it is bound to be accepted beyond any possibility of question or dispute. He has therefore designated these cusps in accordance with their order of appearance, as follows: The antero-external or primitive cusp, the *protocone;* the internal or lingual cusp, the *deuterocone,* and the postero-external, the *tritocone.*

While this order of addition and development of the cusps has thus been shown to be true of the premolars, it is held by Osborn to have been otherwise in the molars. For the sake of rendering his position perfectly clear, I quote at some length from his otherwise excellent paper on the "Structure and Classification of the Mesozoic Mammalia."† He says: "If, as now seems probable, the derivation of the mammalian molar from the single reptilian cone can be demonstrated by the comparison of a series of transitional stages between the single cone and the three-cone type, and from the latter to the central tritubercular type, the separate history of each cone can certainly be traced throughout the series in its various degrees of modification, development, and degeneration. The

* Proc. Acad. Nat. Sci. Phila., 1892, p. 405.
† Jour. Acad. Nat. Sci. Phila., 1886, p. 242.

remarkable part played by the tritubercular molar has been unfolded by the discoveries and writings of Cope. It is undoubtedly the ancestral molar type of the Primates, the Carnivora, the Ungulata, the Cheiroptera, the Insectivora, and of several, if not all, of the Marsupialia. For example, we can trace back the quadritubercular bunodont, or parent ungulate type, to the *tritubercular;* this to the type with three cones in line, which we may call the *triconodont* type, and this in turn to the *haplodont* reptilian crown. A nomenclature may be suggested for these cones, with reference to their order of development and primitive position, to keep clearly before the mind their homologies during secondary changes of form and position. The primitive cone may be called the *protocone;* upon the anterior and posterior slopes of which appear, respectively, the *paracone* and *metacone.* After the tritubercular crown is produced *by the rotation of the lateral cones, inwards in the lower jaw and outwards in the upper jaw,** the *hypocone*, or heel, is developed, giving us the tubercular-sectorial molar." We thus have the statements clearly and distinctly set forth, (1) that upon the single cone there were at first developed cusps upon its anterior and posterior slopes giving a linear arrangement, the "triconodont stage"; and (2) that these anterior and posterior cusps rotated outward in the upper jaw, leaving the main, primitive, or principal cusp, the *protocone*, at the internal or lingual apex of the triangle, the "tritubercular stage." The primitive element or that which answers to the single conical cusp of the simple premolar is thus supposed to be homologized and located in this type of molar crown. For want of a more appropriate term I will designate this view as the Theory of Cusp Rotation or Migration.

As far as I am able to discover, the only direct paleontological evidence in favor of such an explanation is to be found in the lower molars of *Spalacotherium*, in which there is a certain appearance of this rotation of the cusps, as assumed by Osborn, but, as far as I know there are no molars of the upper jaw which furnish any support whatever to such a view. Aside from this almost total lack of evidence in its support, the objections to this explanation are of such an insuperable character that it is scarcely worthy of serious consideration. In the first place, it appears so inherently improbable that in the matter of cusp development, the premolars have had one history and the molars another, that the evidence would require to be of the most direct and positive kind even to place such a proposition on the ground of reasonable probability.

The order and manner of cusp addition, as pointed out by Scott in the premolars, are grounded upon the most indisputable facts, and hence are entirely removed from the realm of

* The italics in this last sentence are mine.

speculation. If we now turn our attention to the case before us, we observe in *Dissacus* the structure of the molars to be so astonishingly like that of the fourth premolar, that to my mind there is not the faintest shadow of a doubt that the postero-external and internal cusps have been added to the primitive cone *in exactly the same manner, and precisely the same order*, as they have been in the premolars. The significance of the disparity in size between the external cusps, just as in the fourth premolar, is explained by the fact that the postero-external cusp is in an incomplete or transitional stage of development. It does not seem reasonable to me that any other interpretation can be placed upon it. The truth of this assertion and the correctness of this interpretation become apparent at a glance, when we compare them with the molars of *Mesonyx*, for in the latter, as we have already seen, the two external cusps are equal in size. That they became so in the course of, and as a result of, a long series of modifications reaching over nearly the whole of Eocene time, establishes beyond any possibility of doubt the further fact that in this phylum we are dealing, not with a degenerating molar crown, but with one which was progressively increasing in complexity.

It will thus be seen that in this case, the evidence is *overwhelmingly* in favor of the view that the addition of the two cusps in question has taken place in a manner very similar to, if not *absolutely identical* with, that of the premolars, and equally opposed to the view embodied in Osborn's theory of rotation or migration. If the disparity in size between the external cusps of the molars of *Dissacus* thus finds a true and satisfactory explanation, the similar condition of these cusps of the first and second molars of *Viverravus*, *Oödectes*, *Vulpavus*, *Neovulpavus*, *Uintacyon*, *Prodaphœnus*, and many others, must be interpreted in the same way. It therefore follows by inference that the tritubercular molar in the entire order Carnivora has been formed in this manner, and not by any supposed rotation or shifting of the cusps, as assumed by Osborn. If in the Carnivora the tritubercular crown has been formed in the same way that it has in the premolars, what shall we say of the other orders in which we do not have the first vestige of evidence beyond that afforded by the premolars?

I have deemed this matter of sufficient importance to go into it thus fully for the reason that a very elaborate and complicated system of nomenclature has been built up by Osborn upon what I fully believe to be an erroneous foundation. The manner of origin of these cusps having been incorrectly determined, it follows that the homologies are wrong, and the names applied inappropriate and misleading. They should therefore be abandoned, since they can be productive only of confusion and error in any attempt at further progress in the subject.

[To be continued.]

Art. V.—*A Cosmic Cycle;* by Frank W. Very.

Forms suggesting the existence of tremendous explosive agencies in nature are familiar to every student of astronomy. Ranyard, in his completion of Proctor's "Old and New Astronomy," has called attention to numerous examples.* In thinking over the probable meaning of these forms and casting about for a sufficient cause for such powerful exhibitions of force, I have been led to consider an explanation which involves an extension of the doctrine of the conservation of energy. Before proposing it I must recall a few facts and commonly admitted hypotheses.

Solar Phenomena.

A few consequences of the contraction theory of the origin of the sun's heat may be briefly summarized:

The transformation of potential energy of position into molecular and atomic kinetic energy produces increasing temperature of the solar mass. A scattered meteor-swarm, by myriads of internal impacts between component meteors, is gradually changed from a collection of massive solid fragments into a liquid nucleus surrounded by a diminishing meteoric swarm† with an interpenetrating gaseous atmosphere; and as the liquid nucleus increases, its temperature and pressure rise until the center also becomes gaseous, and the critical stage is passed, after which no amount of pressure can liquefy the mass. Further condensation, giving increase of pressure, simply raises the temperature. But it is obvious that there must be some limit to the process, and the accepted hypothesis is that after a certain stage of condensation has been passed, radiation increases with temperature at a more rapid rate than temperature as a result of condensation.

This brings us at once to the problem of the mode of dispersal of the thermal energy produced throughout the mass. Since this dispersal can only be effected at the outer surface, there must be a transferring of thermal energy from center to surface at a sufficiently rapid rate to supply the surface output. Conduction proceeds too slowly for this purpose. Convection is competent to perform such a function up to a certain point and is also evidenced by the phenomena of the solar spots; but since viscosity, which impedes convection, increases with temperature, it may be doubted whether convection, in turn, is

* See especially Arts. 1421, 1424, and the end of 1445.

† The zodiacal light possibly represents the last remnant of such a swarm in our own system.

able to follow the demands put upon it for the disposal of thermal energy produced by contraction. Our sun has already reached the stage where viscosity is sufficient to cause the retention of abnormal distributions of heat in particular localities, since spots frequently recur in the vicinity of the same heliographic latitude and longitude.

There is a third mode by which internal energy may be brought to the surface, namely, by some explosive force of sufficient power to overcome the enormous resistance of pressure. Such a force is witnessed in the production of explosive solar prominences whose angles of divergence prove that their point of origin is at a considerable depth. Cases of simultaneous spots or prominences on opposite sides of the sun are known. Here it is possible that an originating explosion at the very center of the sun has started a commotion powerful enough to reach the surface. At the center the pressure is presumably greatest. If this pressure is for any reason a critical one, limiting a condition of unstable equilibrium, a sudden increase or decrease of pressure may precipitate an explosion. Such an unstable condition exists when water in the spheroidal state remains suspended over red-hot metal. Sudden lowering of pressure, obliterating the intermediate layer of steam, produces complete contact of water and metal, and starts an explosion.

Within the sun, I shall assume that increase of pressure, due to contraction, accumulates from time to time until it surpasses a certain critical point, depending upon some condition of the mass which remains to be determined, and that explosion occurs (or a series of explosions), restoring equilibrium temporarily.

Since centrifugal force diminishes gravitational pressure as the equator is approached, ascensional motions produced by central explosions can more easily reach the surface near the equator. In this way a surface layer of relatively hot material will tend to accumulate in a broad equatorial zone, and where the horizontal surface temperature-gradient is steepest, let us suppose somewhat nearer the equator than midlatitude, convectional storms begin, gradually approaching the equator as the disturbing layer of hot material is used up. Increasing radiation during the stormy period produces more rapid contraction and restores the central critical pressure. The solar spots being local phenomena may be influenced by various subordinate causes, such as the fall of meteoritic matter on certain regions of the solar surface, and minor irregularities of spot-sequence may be produced in this way; but the general sun-spot period, being due to the deep-seated circulation, should exhibit a constancy and stability proportionate to the magni-

tude of the operations by which it is directed. Professor Newcomb's conclusions* on this point are entirely favorable to the view that the cause of the solar period of 11.13 years is internal and deep-seated.

If the velocities due to central explosions are great enough to enable some portions of central material not only to reach the surface but to penetrate the photosphere and emerge as coronal streamers, these must be most concentrated in the equatorial regions; also those streamers emerging in high latitudes will fall behind the general rotation as they ascend, and will appear to curve away from the axis. Since as directly viewed from the earth's northern hemisphere, the rotation is from left to right, the polar filaments on the nearer side of the sun's northern hemisphere will appear to curve to the left up to an axis of symmetry somewhat to the right of the axis of rotation. Observations on this point are conflicting, which may imply that the coronal substance is of a transparent sort, and that the brightest streamers at the poles are sometimes on the nearer, sometimes on the farther side. Spreading, or forked streamers will be produced if members on opposite sides of the pole are superposed. The general form produced by central explosive agency is masked at sun-spot maxima by luminous curving and tree-like structures emitted in various directions, especially over the sun-spot zones.

Stellar Explosive Agencies.

In seeking a possible cause for explosions of cosmical magnitude, it seems to me that we must be guided by something like the following considerations: The lower orders of material substance are successively limited. In ascending towards their sources they throw off their outer coverings and expand into fuller freedom and potency. A block of ice has but little power of internal (thermal) motion. Transformed into water it has a greater activity. As steam it lifts great weights. Resolved into its chemical constituents, it becomes a dangerous explosive. Tear its atoms asunder and gigantic solar maelstroms ensue at whose turmoil distant worlds may tremble.

The analogy should not be pushed too far. The breaking up of the atoms must follow new lines, must indeed be, in some respects, opposed to the processes which produce change of state in the molecular condition. Heat disappears in the rarefaction of matter. It should be evolved in its destruction.

The grosser material substances change with the progress of time. Their underlying atoms seem more permanent; nevertheless, these also have a history, and have passed through an

*S. Newcomb, *Astrophysical Journal*, vol. xiii, p. 1, 1901.

exceedingly prolonged series of changes, slowly moving onward to a final dissipation. The great aggregates of elementary, atomic, and molecular movements, which we call suns and planets, may endure; but the parts of which they are composed, though their existence may comprise ages of the natural life of man, seem to be, in the nature of things, limited both as to time and as to space. A limit in space we see in the respect that matter, as such, is not infinitely subdivisible, but at certain limiting orders of magnitude critical points are reached at which the mode changes, pointing to an ultimate limit of dimension at which matter may be said to originate.

It would take too long to discuss the rich material, bearing on the subject of atomic resolution, which Sir Norman Lockyer has been accumulating for many years; nor does it seem necessary to do so in this connection, since the present suggestion, while deriving support from these valuable observations, is to a certain extent independent of them.

Lockyer's spectral researches indicate modifications in the spectra of the elements at certain stages of stellar evolution. The whitest stars have extensive outer envelopes of hydrogen and helium, but simplified metallic spectra. Mr. Frank McClean adds oxygen to the list of constituents in the atmospheres of the helium stars,* and the photographs of stellar spectra by Sir William and Lady Huggins confirm this, the oxygen triplet (λ 4070, 4072, 4076), and the strong nitrogen line, λ 3995, appearing plainly in the spectrum of γ Orionis, and other lines faintly in this and other stars of McClean's Div. 1, *b*. The modified spectra which Lockyer attributes to proto-elements, may be phenomena analogous to allotropism, dependent on temperature conditions, but at any rate they demonstrate a lack of fixity in elemental characteristics at temperatures which forbid all union of unlike elements, so that the only changes possible are supra-elemental.

The peculiar spectra of the white stars also show a special arrangement of their constituents, or at least a special condition which prevents the exhibition of a large number of elements. We are thus compelled to include both chemical and physical facts in our classifications.

Stellar Classifications.

The arrangement of stars proposed by Mr. Frank McClean contains the essential features of a natural system, and is not too complex for the presentation of a few leading principles. Omitting minor details, we have six groups: Div. 1. Orion

* "Comparison of Oxygen with the Extra Lines in the Spectra of the Helium Stars, etc." *Astrophysical Journal*, vol. vii, p. 367, 1898.

or helium stars. Div. 2. Sirian or hydrogen stars. Div. 3. Procyon or hydrogen-iron stars. Div. 4. Solar or calcium stars. Div. 5. Stars with unknown flutings. Div. 6. Stars with hydrocarbon flutings.

The division of stellar spectra proposed by Sir William and Lady Huggins* rests upon the character of the hydrogen spectrum alone, and is hardly complete enough for my purpose, but its simplicity recommends it. Three conditions are noted:

"(1.) All the lines thin, defined and very distinct up to the end of the series.

(2.) All the lines winged and strong, but more or less indistinct, and incomplete in number, as the end of the series in the ultra-violet is approached.

(3.) In the photographic region the first three lines only, namely $H\beta$, $H\gamma$, $H\delta$, more or less thin and defined, the line $H\varepsilon$ diffuse, and the lines beyond practically absent, probably through excessive diffuseness."

In addition to these features, hydrogen types (1) and (2) show a broad diffuse band of absorption from $0{\cdot}35\mu$ to $0{\cdot}37\mu$, which is wanting in (3), and which does not seem to have been noted before. Since the intensity of this diffuse absorption is proportional to the breadth of the ultra-violet hydrogen lines, and since its position is associated with the vanishing point of their harmonic rhythmical succession, there can be little doubt that the band is due to the same substance.

Huggins' hydrogen type (2) will include McClean's divisions (2) and (3). It is suggested by Sir William and Lady Huggins that the fading out of the more refrangible members of the hydrogen series in the solar stars is due to interference with these atomic vibrations by the simultaneous vibrations of associated metals which have powerful absorption in the same region (*loc. cit.*, p. 104).

Heat of the Stars.

The question of relative stellar temperatures is of fundamental importance. Sir William and Lady Huggins, from their photographs of ultra-violet and violet stellar spectra, conclude that solar stars have hotter photospheres than Sirian. The argument is as follows: Comparing the violet spectra of such stars as *Capella*, which culminates at $5\frac{1}{2}°$ from the zenith at Tulse Hill, and *Vega*, whose meridian zenith distance is $12\frac{1}{4}°$, and where, consequently, the spectra have been but little changed by the absorption of the terrestrial atmosphere, it is seen from photographs taken under as nearly as possible identical conditions that, although, as a whole, the violet region

* *An Atlas of Representative Stellar Spectra*, p. 154–155.

in the spectrum of the solar star is very much darker on account of the multitude and intensity of the Fraunhofer lines, yet the narrow breadths of unabsorbed spectrum between the lines are brighter in *Capella* than in *Vega*. In the extreme ultra-violet the energy in the spectrum of the Sirian star everywhere prevails, but here it is probable that the general absorption of the short waves by the atmosphere of the solar star has increased at a more rapid rate, so that even the intervals between the absorption lines are obscure. The comparison in the ultra-violet, to be of any value, must be made beyond the broad band of diffuse absorption in the spectrum of the Sirian stars ($0{\cdot}35\mu$ to $0{\cdot}37\mu$), and since the general absorption of the earth's atmosphere is here both large and variable, the result might be of doubtful interpretation.

As the general absorption becomes small in the yellow, we may anticipate that the interlinear supremacy of the solar star will be found still greater in this part of the spectrum, and the test is worth trying with iso-chromatic plates. Of course it will be understood that the average brilliancy of the spectrum of a solar star through a considerable range, without regard to minor fluctuations, is relatively greater towards the red than in the violet, because of the smaller number and intensity of red absorption lines, and this seems to be even more the case in the infra-red.

Professor E. F. Nichols has determined the ratio of the total radiation from *Arcturus* and *Vega* as 2·2.* There is no such difference of brightness in these two stars. Their visual intensities scarcely differ by 0·1 magnitude, while in the ultra-violet *Vega* is the more intense. Consequently the total radiant superiority of *Arcturus* means that it has not only absolutely, but also relatively, a greater intensity than *Vega* in the infra-red, and that the maximum energy in the spectrum of *Arcturus* is of a greater wave-length than *Vega's* maximum. This proves that the effective surface-temperature of *Vega* is the greater. The meaning of this may be open to various interpretations. It is possible that all photospheric surfaces are at substantially the same temperature, the position of the photosphere being determined by the level at which this temperature is attained, and that variations of intrinsic brightness or of distribution of energy in the spectrum are entirely due to absorption by the stellar atmospheres. In this view the photosphere of a solar star is situated at a greater depth below the surface than in a Sirian star, and the preponderance of selective (line) absorption for the violet and ultra-violet rays by the solar atmosphere, as well as the greater general obstruction to

* *Astrophysical Journal*, vol. xiii, p. 135, 1901.

the passage of rays of short wave-length, has displaced the solar maximum towards the infra-red.

Although the temperature of the deeper portions of a star may increase as it contracts, its effective surface-temperature, as measured by its radiation, progressively diminishes. For proof of this in the case of our sun, we have only to refer to geologic evidence.

Tropical forms of life occur in higher latitudes as we go back through the geologic ages. "The general climate cannot be sensibly affected by conducted heat (from the earth's interior) at any time more than 10,000 years after the commencement of superficial solidification."* Retention of radiation may be altered temporarily by slight modifications of the earth's atmosphere produced by volcanic eruptions or by meteoric accessions; but the continual lowering of terrestrial temperature is evidence of a steady diminution of solar efficiency, partly because the angle subtended by the solar sphere has grown smaller, and partly because the absorption of the solar atmosphere has become greater.

The safest criterion of a progressively deepening photospheric surface and increasing stellar atmosphere is the cessation of the shorter waves as a whole. If we choose the breadth of a line in the spectrum as a signature of pressure, we shall get a different estimate of the density of the stellar atmosphere according to the substance selected. Thus great breadth of the helium lines would accuse some of the Orion stars of having the densest atmospheres—hydrogen would speak for the Sirian stars to the same effect—calcium for the solar stars, and so on.

Spectral Variations connected with Changes of Density.

As helium glows in the solar chromosphere without manifesting its presence by any dark Fraunhofer lines, we are not permitted to infer the absence of a substance from sun or star by the failure of its spectral lines. Helium exists about the sun as an elevated and rarefied shell. The seldom varying breadth of its chromospheric lines from the limb up to a height of about one thousand miles, and the smaller distortion of the lines, show that, unlike hydrogen whose chromospheric lines are often broadened and distorted, the helium atmosphere is comparatively quiescent and probably greatly rarefied.†

* W. Thomson (Lord Kelvin), *Trans. R. Soc. Edinburgh*, vol. xxiii, pt. 1, p. 164, 1862.

† In Frost's translation of Scheiner's "Astronomical Spectroscopy" (p 189, 1894), it is said that "the D_3 line presents an entirely different appearance [from that of the hydrogen lines in the chromospheric spectrum], for while following the shape of the prominence in general, it never broadens at the limb, but on the contrary grows narrower, and possibly it does not touch the limb at all. This would indi-

Coronium floats at a still higher level than helium, and it likewise appears to lack representation among the Fraunhofer lines, the old supposed identification having proved erroneous. We may presume that if any other ingredient of the sun's reversing layer were removed to such an altitude as to be greatly expanded, its dark Fraunhofer lines would disappear from the spectrum, unless one or more of them might linger by virtue of extraordinary intensity.

In a different category belong those elements of great density which at a certain stage of condensation may be deeply buried and thus fail to appear, but which may afterwards be brought to the surface. In this case are those metals whose lines first begin to show feebly in the spectra of the Sirian stars.

Nevertheless, although the apparent absence of an element may be explained in some such way, these explanations do not rule out the possibility that the apparent absence or weakening of an element in a star may be due to an actual elimination. Still less can they be invoked either to prove or disprove the possibility of such a general breaking down of atomic structures as I have suggested.

Pressure produces great spectral changes. "The whole character of the spectrum of iron, for instance, is changed when we pass from the Fraunhofer lines to those seen among the spot and prominence lines; a complex spectrum is turned into a simple one, the feeble lines are exalted, the stronger ones suppressed almost altogether."* We know that a very wide range of pressure must exist in different stars and at different stages of condensation in the same star. A first effect of condensation is an increasing heterogeneity and a separation of ingredients into successive shells of varying composition,

cate that helium has a less density near the limb than in the higher strata of the solar atmosphere." With greater dispersion, however, this constriction at the limb is not seen, but the line appears hazy and of uniform breadth through the greater part of its length, becoming fainter and narrower at its upper extremity. With still greater dispersion, according to Hale, the helium lines broaden in the lower part of the chromosphere much as the hydrogen lines do. These distinctions, therefore, depend entirely upon the brilliancy of the background of continuous spectrum on which the bright lines are superimposed. The distribution of luminosity on either side of the center of the line is not the same in these two cases. The hazy wings of the hydrogen lines diminish more gradually in intensity on receding from the center. The broad wings of helium are hard to see near the limb, consequently helium falls off very suddenly in brightness on either side of the center of a line, and it is probable that in this respect the curve of emission for a helium line (coördinates = wave-length and intensity) resembles the curve of absorption very closely, and that this is a principal cause for the feebleness of the helium absorption lines. But it cannot be the only reason, since helium appears dark in stellar spectra, and the cause suggested in the text may be an additional one for its non-appearance in the solar spectrum.

*J. Norman Lockyer, *The Chemistry of the Sun*, p. 253.

and this will produce spectral differences according to the level of the absorption; but the spectral differences to which Lockyer refers are of another sort and favor the interpretation that there has been a breaking down of the more complex atoms and an increase of simpler atoms, either relatively by the disappearance of the more complex, or possibly by a transformation of the complex into simpler forms. If we suppose that those atoms having large atomic weights have been formed by the expenditure of a greater energy, or that their latent heat of formation is relatively very great, the transformation of heavy atoms into lighter ones will set free an amount of energy equivalent to the difference in the heat of formation;* but whether produced by transformation or destruction of atoms, the setting free of latent heat of atomic formation ought by analogy to develop relatively larger amounts of heat, or of energy to use a more elastic term, than transformations in the more compounded states of matter; and this development of energy may increase with rising temperature and excessive condensation, until limited in another way; for since the pressures produced by gravitation must be greater in very large masses, it is probable that the explosive energy developed by atomic transformation will increase as a complex function of the mass and its condensation; and thus explosive energy may be so great as to rupture the mass when this exceeds a certain size and degree of condensation. Star clusters may have resulted from such cataclysms in stars of very great mass. So many of the spiral nebulae consist of similar curved arms emanating in opposite directions from a common center, that we seem driven to admit the existence of directed explosive forces of enormous magnitude.

On June 26, 1885, at $1^h\ 25^m$ Paris mean time, Trouvelot† saw two prominences of extraordinary height at opposite extremities of a solar diameter (position angles, 59° and 239°). The eastern prominence measured 10.′5, or about a third of the solar diameter, and the other was nearly as large. The western prominence, which was observed in its active stage, is thus described: "Its aspect was tree-shaped, and from its base, which resembled the root of a Pandanus, rose a slightly wavy column, 5′ high, perpendicular to the surface, and ramifying into numerous branches which diminished in brilliancy as they rose, for the most part becoming invisible before their summits

* It will be noticed that the meaning of the term "heat of formation" is extended beyond its usual application; but since heat is understood to be the energy of motion of the invisible constituents of bodies, it is appropriate enough to apply the same form of speech to the corresponding activity of the atomic constituents.

†. E L. Trouvelot. "Remarquables protubérances solaire diamétralement opposées." *L'Astronomie*, vol. iv, p. 441, 1885.

could be recognized" (p. 442). M. Trouvelot says: "We knew already that great prominences show themselves quite frequently at the ends of the same diameter, and we even suspected that a relation existed between them; but as these objects often occupy quite a considerable extent upon the sun, it was difficult to determine whether their being met at diametrically opposite points was a simple coincidence, or whether they were in relation and obedient to a common cause. The observation of the 26th of June seems to be in favor of the last supposition."

Secchi says:* "M. de la Rue has remarked that great spots are generally situated at the extremities of the same diameter. The same law also applies very often to the development of great prominences. This coincidence agrees well with the hypothesis of an action analogous to that which produces the tides."

An examination of the longitudes of the planets on June 26, 1885, shows that Mercury and Saturn were nearly in line with the earth, but the tide-raising power of the combination does not seem great enough to produce such an extraordinary effect as that of the gigantic prominences seen by Trouvelot.

Evidences of Explosions within the Stars.

As Ranyard has pointed out, instead of the doctrine that the stars are products of condensation from nebulae, could be equally well substituted the opposite one that the nebulae have been thrown out explosively from previously existing stars, without doing violence to the appearances; and it may be that both processes are real, and that a criterion for distinguishing between them should be sought.

The curved streaks of nebulosity in the *Pleiades* appear to have some connection with the stars. The largest stars: *Alcyone*, *Maia*, *Electra*, and *Merope*, are in the midst of nebulae, and some of the streaks, especially those around *Maia*, have forms which at least are not inconsistent with the supposition that they may have emanated from the star at various times.

Miss Clerke† computes as a possible minimum value of the distance of the *Pleiades*, 1,500 billions of miles, or 250 light-years. "An assemblage like the *Pleiades* distributed round our sun would extend *compactly* three-quarters of the way to *α Centauri*, its feelers and appendages indefinitely farther."‡ The brilliancy of the brighter stars in this case is several hun-

* *Le Soleil*, 2e ed., vol. 1, p. 192, Paris, 1875.
† Miss Agnes M. Clerke, *The System of the Stars*, p. 226.
‡ *Loc. cit*, p. 227.

dred times that of our sun. Their masses may even now exceed the limit demanded by the explosion hypothesis.

From some of the stars, nebulous arms proceed on opposite sides. Here the explosion has not been strong enough to blow the star to pieces; but more complex interlacing structures, and clusters of stars come either from successive explosions, or from a single one of such power as to produce disruption along a multitude of diverging paths. A sufficiently powerful explosion will give free wandering stars; and globular clusters, in this view, are relatively transient associations. The ultimate fate of aggregations formed in such a manner must be to break up. The star sprays and star drift noted by Mr. Proctor in his "Universe of Stars" may have resulted from such dispersals. The government of the heavens is like that of a great republic. No regal orb compels allegiance of a host of inferiors. The solar system is a family, where the relations of parent and child are recognized; but the stellar universe is a brotherhood, in which freedom and equality reign.

This view distinctly traverses the conception which has prevailed hitherto: that star-clusters are agglomerations condensed by the attraction of gravitation. If this were so, those clusters in which the action has been going on longest should be the most highly condensed. Instead of this, we find the most open and least typical clusters, such as *Coma Berenices*, to be those which include the greatest variety of stellar spectra and the most advanced types.*

The splitting of a star in two by a directed explosion at its center should, in general, originate two equal motions in opposite directions in the equatorial plane, for the reason that centrifugal force diminishes the pressure in this plane of which some particular diameter is liable to form a line of least resistance.

As the outer layers are not concerned in the explosion, they remain at rest and constitute inert envelopes which will be dragged along by the moving parts, retarding them and perhaps at last destroying their motion by friction. The result will be a pulling out of the material of the star into finger-like extensions whose form, persistent through the partial or perhaps complete destruction of relative motion, will depend upon the relative velocities of the original rotation and proper motion, combined with the varying velocity due to the explosion, as the motion is gradually overcome by friction.

Except in the rare case of a star without proper motion, or of one whose proper motion is in the equatorial plane, the

*Compare E. C. Pickering aided by M. Fleming, "Miscellaneous Investigations of the Henry Draper Memorial," *Ann. Harvard Coll. Obs.*, vol. xxxvi, part 2, Table 29, p. 283, 1897.

resulting double spiral or sigmoid curve of the combined trajectories cannot lie in one plane. Moreover, the two arms will not be entirely symmetrical, but both will lie on that side of an equatorial plane through the origin of motion towards which the direction of proper motion points, and unless the proper motion is directed at right angles to the original equatorial plane, the two branches will have different curves. Figures of this sort have been found by Holden* from a comparison of a considerable number of spiral nebulae, and Keeler's crowning work with the Crossley reflector indicates that the number of spiral nebulae is very large.

Friction during the transformation must largely overcome the original rotation. Any remnant of rotary motion is probably confined to the original nucleus or to nuclei at the tips of the horns. In the absence of original rotation or proper motion, the result of an explosion will be a straight nebulous ray, which may retain a central nucleus and two subordinate ones symmetrically disposed in the tips. Many other varieties will suggest themselves. The stars *Asterope* (Wolf No. 121), mag. 6·5; Wolf No. 129, mag. 7·0, and Wolf No. 182, mag. 7·5 in the *Pleiades*, terminating curved nebulous streamers from *Maia*, mag. 4·5, may serve as an example.

The existence of a few "run-away" stars, with velocities much exceeding those which gravitation can produce, suggests that under rare circumstances explosions may occur through a large part of a stellar volume, so that the remnant thrown off is not much retarded by the resistance of outer inert layers.

*E. S. Holden, "On the Helical Nebulae." *Pub. Astr. Soc. of the Pacific*, vol. i, p. 25, 1889.

[To be continued.]

SCIENTIFIC INTELLIGENCE.

I. Chemistry and Physics.

1. *Chemical Reactions Produced by Radium.*—Berthelot has made a series of experiments upon the chemical action of the rays emitted from a small sample of radium chloride (about 0·1g.), which had been obtained from M. Curie. The active salt was contained in a small hermetically sealed glass tube, and for the purposes of experiment this tube was enclosed in a second tube, so that the rays were obliged to traverse two glass walls where the substance to be experimented upon was in contact with the outer tube, while three layers of glass were interposed when the radium acted from without a vessel containing the substance. It is possible, if radium rays vary as light rays do, that a part of the active rays may have been intercepted by the glass. The experiments were performed in the dark, with the use of parallel experiments without radium for comparison. It was found that solid iodine pentoxide was decomposed by the radium rays, as by light, into iodine and oxygen, while concentrated nitric acid, in the same manner, became yellow. These two reactions are endothermic, hence it is shown that the rays supply chemical energy. On the other hand, it was shown that several exothermic reactions were not produced by the rays. The conversion of rhombic sulphur in carbon disulphide solution into insoluble sulphur, which is caused by the action of light and is slightly exothermic, was not produced by the radium rays. The exothermic polymerization of acetylene gas, which is induced by electric effluvia, but not by light, was not effected by the radium. Oxalic acid, which is oxidized by atmospheric oxygen even in diffused light, did not undergo this oxidation under the influence of the radium rays. It was found further, as had been previously noticed, that the glass in which the sample was contained was blackened, evidently from the reduction of lead, while near the blackened regions a violet tint, probably due to the oxidation of manganese, was observed.—*Comptes Rendus,* cxxxiii, 659.

Soon after the appearance of Berthelot's article, which has been noticed above, Becquerel published a note upon the same subject. Attention is there called to the fact that salts of barium containing radium are spontaneously phosphorescent, so that in making experiments with them the phosporescent light should be cut off by the use of black paper or a thin sheet of aluminum foil. He observes that the production of ozone by radium rays, which has been noticed by M. and Mme. Curie, is an endothermic action analogous to those observed by Berthelot. The chemical action of the rays in their photographic behavior is recalled, as well as their strong coloring action on glass, porcelain, paper, rock-salt and sylvine, their alteration of barium.

platinocyanide, and their destructive action upon the skin. He mentions two exothermic reactions that have not been previously noticed: the conversion of white phosphorus into the red modification, and the reduction of mercuric chloride to mercurous chloride in the presence of oxalic acid in solution. He mentions finally the interesting fact, recently observed in his laboratory, that seeds exposed to radium rays for a long time before planting do not germinate. This action is slow, for little effect is noticed after 24 hours, but it is effective after a week or more.—*Comptes Rendus*, cxxxiii, 709. H. L. W.

2. *The Preparation of Nitrogen from Ammonium Nitrate.*—In attempting to prepare nitrous oxide, N_2O, by the decomposition of ammonium nitrate, the plan of heating this salt with a high-boiling solvent suggested itself to J. Mai. Upon using glycerine for this purpose (50g. glycerine with 25g. ammonium nitrate), and heating to 190°, a gas began to be given off, and this continued without further heating until the temperature fell to 150°. After this a regular stream of gas could be obtained by heating to 160° or 170°. It was found that the addition of a few drops of concentrated sulphuric acid to the original mixture lowered the temperature at which the gas came off at first. Upon examining the gas it was found to be nearly pure nitrogen instead of the expected nitrous oxide, and it was shown that oxidation of the glycerine to glyceric acid had taken place. It is possible that the method may be useful in preparing nitrogen on the large scale, and it may be expected that the method of oxidizing organic substances will be useful in other cases besides that of glycerine.—*Berichte*, xxxiv, 3805. H. L. W.

3. *The Atomic Weight of Tellurium.*—According to the position of tellurium in the periodic system of the elements its atomic weight should be less than that of iodine, but the most reliable determinations that have been made in the past have given results which indicate an atomic weight somewhat above 127, while that of iodine is considered to be 126·85 (oxygen being taken as 16). Pellini has recently made some new determinations of the atomic weight, using tellurium which had been purified by the recrystallization of diphenyl-tellurium-dibromide, and by distilling the elementary substance in a vacuum. The determinations were carried out by converting weighed quantities of tellurium into the dioxide and weighing the latter, and also by the reverse of this operation. Fairly satisfactory agreements were obtained, and the average of the results indicates an atomic weight of 127·6, which is in close accordance with the value found by several other investigators.—*Berichte*, xxxiv, 3807. H. L. W.

4. *Artificial Spinel.*—Although this mineral has been prepared artificially by several chemists, it is interesting to notice that Dufau has found a very simple method of forming it by means of the electric furnace. An intimate and well calcined mixture of 200g. of alumina and 100g. of magnesia is heated in a

carbon crucible for three minutes by means of an arc of 900 amperes and 45 volts. A crystalline mass is formed containing cavities lined with crystals. The crystals of spinel thus formed are colorless, octahedral, scratch quartz, have a specific gravity of 3·57 at 15°, and have a composition corresponding to the spinel formula $MgAl_2O_4$. It is easy to obtain colored spinels in this way by additions of small quantities of oxides of nickel, iron, chromium, cobalt, etc. Attempts were made to prepare more basic magnesium aluminates by fusing alumina with several molecular proportions of magnesia, but spinel was invariably formed, crystallized in the excess of fused magnesia.—*Bull. Soc. Chim.*, xxv, 670. H. L. W.

5. *The Size of the Sulphur Molecule.*—Biltz and Preuner have made an elaborate series of determinations of the specific gravity of sulphur vapor under diminished pressures which varied from 14 to 539^{mm} and at the temperature of sulphur boiling at atmospheric pressure, or between 447 and 450°. At the lowest pressures used the specific gravities corresponded to molecules a little heavier than S_4, and as the pressure increased the specific gravities rose rapidly to values corresponding to S_3, S_6 and S_7, and then increased very slowly. The results when plotted indicate a curve beginning at S_2 at 0^{mm} and approaching S_8 at high pressures. The authors conclude that sulphur vapor consists wholly of S_8 and S_2 molecules, and that there is no evidence of the existence of the previously assumed S_6 aggregations.—*Monatsh. f. Chem.*, xxii, 627. H. L. W.

6. *A Direct Gravimetric Method for the Estimation of Boric Acid.*—It has been found by Partheil and Rose that it is possible to extract boric acid, from an aqueous solution acidified with hydrochloric acid, by means of ether. The extraction apparatus used is one which acts continuously, the ether being distilled and condensed in such a manner that it flows up through a spiral tube containing the liquid to be extracted and then overflows into the distilling-flask. An extraction lasting 18 hours was found desirable, and the ether finally remaining in the flask was removed in a vacuum desiccator over sulphuric acid in order to weigh the boric acid as H_3BO_3. Two test analyses on boric acid and borax gave very accurate results, and the authors state that they have applied the method to the analysis of many minerals. For the application of the process, the boric acid solution should contain neither sulphuric, phosphoric nor nitric acids, nor any considerable amount of iron. The presence of zinc and arsenious acid would also interfere with the operation.—*Berichte*, xxxiv, 3611. H. L. W.

7. *The Pressure of Light.*—Two papers have recently appeared on this subject: E. L. Nichols and G. F. Hull in the Physical Review, November, 1901, and P. Lebedew in the Ann. der Physik, No. 11, 1901. The investigators employ similar apparatus—vanes of varying material, suspended in a vacuum. They distinguish carefully the radiometer effects from the pressure of

light effects. Professors Nichols and Mr. G. F. Hull obtain $P = 1{\cdot}05 \times 10^{-4}$ dynes; theory demanded $P = 1{\cdot}34 \times 10^{-4}$ dynes. They believe that the observations show the existence of the phenomenon. Lebedew gives complete details of the construction of his vanes, which were of many forms, and of the method of exhausting his vessel. He used the most modern form of vacuum pump, shunning as far as possible complications due to greased joints. After as complete an exhaustion as possible, a globule of mercury in the vessel which contained the vanes was heated and after a renewal of the exhausting process the vessel was cooled. The value obtained for the pressure of light on an absolutely black body was $P = 0{\cdot}0000258$ dynes. This pressure is directly proportional to the quantity of the incident energy and independent of the color of the light. Lebedew considers that the existence of the Maxwell-Bartoli pressure of light has been proved.—*Ann. der Physik*, No. 11, pp. 433–458. J. T.

8. *On some Chemical Effects produced by Radium Radiations.*—In the Comptes Rendus of Nov. 4 HENRI BECQUEREL states* that the radium radiation consists of a part capable of deviation in the magnetic field, identical with the cathode rays, and a part non-deviable, a fraction of which is absorbable and the remainder extremely penetrating. Observations are brought forward to show the action of the rays on glass, the transformation of yellow into red phosphorus, the reduction of mercury perchloride in the presence of oxalic acid and the effect upon seeds. It is found that prolonged exposure to the radium radiations had the effect of destroying the power of germinating in the seed.—*Nature*, Nov. 14, 1901. J. T.

9. *On the Induction Coil.*—Lord RAYLEIGH reviews the recent papers of Oberbeck, Walter, Mizuno, Beattie, and Klingelfuss, and considers that the subject is by no means exhausted. The author maintains that highly magnetized iron cannot be regarded as a store of energy, and that the energy expended in producing the magnetization is recoverable to a very small extent. The available energy of a highly magnetized closed circuit of iron is insignificant. The question of the desirability of a condenser in the primary circuit is next discussed, and shows that with a *very quick* break the condenser only does harm. He details experiments to produce such a break; among these experiments are interesting ones with a rifle bullet. The experiments supported the view that the only use of a condenser in conjunction with an ordinary break is to quicken it by impeding the development of an arc. If a sufficient rapidity of break can be obtained by other means, the condenser is deleterious, operating in the reverse direction and prolonging the period of decay of the current. The author does not refer to the Wehnelt interrupter and other forms of electrolytic breaks, which accomplish the object which he desires.—*Phil. Mag.*, Dec. 1901, pp. 581–594. J. T.

10. *Resistance in High Vacua;* by WILLIAM ROLLINS. (Communicated.)—The statement is frequently made that the resistance

*See also p. 59.

to the electric discharge in high vacua follows an inverse rule from that governing discharges at ordinary pressures. In air at atmospheric pressure the resistance increases for moderate distances as the length between the terminals increases, while in high vacua the resistance is said to diminish as the distance between the terminals increases.

If the latter were true it would be so discordant with known laws that I have during several years made experiments with freshly prepared X-light tubes to see what could be learned. I have concluded that the accepted opinion is not correct. When the resistance in high vacua appears to follow another rule from that governing in air it is because the true condition is masked. To show that the same law applies in both cases I mention results obtained from tubes recently prepared for experiments on burning the skin. These had the movable terminals described and figured in my Notes in The Electrical Review for December, 1897, and January, 1898. They were carefully prepared with heat and heavy surges during pumping to get the terminals in proper condition for the current afterward to be used in exciting them. In No. 1, the target (anode) was placed forty millimeters from the cathode. In this position the resistance to an amount of current suitable for the tube was equal to four millimeters of air at atmospheric pressure. When the distance between the cathode and target was increased to one hundred millimeters, the resistance increased to ten millimeters of air.

In No. 2, under the same conditions, the resistance was equal to eight millimeters and twenty millimeters of air. In studying the resistance of high vacua, X-light tubes are valuable as they are very sensitive, and it is important to consider the conditions which determine the production of a regular cathode stream (such as the form of the terminals, the condition of the gas amalgamated with them)—the establishment of a normal circulation of the residual gases (depending on the form of the tube and the relations of the terminals to it)—the amount of the current and the size of the surges which are sent through the tube.

11. *Studies from the Chemical Laboratory of the Sheffield Scientific School;* edited by HORACE L. WELLS.—In two volumes: Vol. I, Papers on General Inorganic Chemistry, pp. 444; Vol. II, Papers on Organic Chemistry, pp. 379. Yale Bicentennial Publications. New York, 1901 (Charles Scribner's Sons). The Chemical Laboratory, which, as "the Philosophical Department of Yale College," had its beginning in 1847, has the distinction of having been the nucleus which has developed and expanded into the vigorous department of Yale University now known as the Sheffield Scientific School. From those early days until the present time the Sheffield Chemical Laboratory has been active in research no less than in instruction. This fact is well brought out by the Bibliography given on pages 4 to 10 of volume I before us, which, however, is limited to the titles of papers (130 in number) published, or about to be published, by the officers at pres-

ent connected with the department and those associated with them in New Haven. From this abundance of material, papers have been selected to fill these two volumes of the Yale Bicentennial Publications. The first volume is confined to inorganic chemistry and includes, for example, the interesting series of investigations by H. L. Wells and others on the halogen compounds of cæsium and other elements.

The second volume contains a varied collection of memoirs on organic chemistry, many of them by W. J. Comstock and H. L. Wheeler. It is obvious that the eight hundred pages available could not suffice for all the memoirs which deserved republication. Some of those not represented here include, in accordance with the plan of the work, all the early papers; also, among recent publications, a series on thermo-chemistry by W. G. Mixter; further, papers on mineral chemistry, which last, however, have in part been included in the related volume noticed on p. 398 of the November number.

12. *Light: A Consideration of the more familiar Phenomena of Optics;* by CHARLES S. HASTINGS, PH.D. Pp. 224. Yale Bicentennial Publications. New York, 1901 (Charles Scribner's Sons).—The physical student, no less than the general reader, will feel himself indebted to Professor Hastings for having taken the time from more serious labors to prepare this very lucid discussion of the fundamental phenomena of optics. The topics included are such as come, more or less fully, within the range of observation of every intelligent person; those involving the use of complex apparatus (e. g. spectroscopy and polarization) being wisely omitted. The method of treatment is uniformly simple and the language and illustrations so far as possible familiar, while the prominent place given to historical development adds much to the interest and value of the whole.

The opening chapter deals with the nature of light as a wave motion, and the resulting explanation of the phenomena of reflection and refraction; this subject is again taken up in the closing chapter, in which the different theories as to the nature of light are discussed from Newton to Maxwell and Hertz. The interference and dispersion of light and some of their consequences are concisely treated, and then follows an admirable discussion of the optical instruments, the telescope and microscope; a chapter is given also to the eye and vision. A particularly interesting portion of the work is that devoted to the varied optical phenomena of the atmosphere; these subjects are of the keenest interest to everyone and yet they are rarely described and explained in such a manner and with such fullness as to be intelligible.

While the matter in hand is to so large a degree familiar, yet there is not lacking an originality in the method of presentation which will make the book valuable and suggestive to the physical student. He will turn, however, with most interest to the appendices, particularly Appendix A, with its mathematical discussion of lens systems. The author's extensive and successful

study into the methods of improving the construction of optical glasses, both for the telescope and microscope, have enabled him to present this subject in a particularly new and valuable form.

II. Geology and Mineralogy.

1. *Lamarck, the founder of Evolution, his life and work, with translations of his writings on Organic Evolution;* by Alpheus S. Packard; pp. 1–451. New York, 1901 (Longmans, Green & Co.).—A very great service has been rendered by Professor Packard in bringing to light so full an account of the views of this most important of the pre-Darwinian writers on evolution. The volume is the result of an assiduous search among the available records of his life-work to be found in the Paris libraries and in the town of Bazentin-le Petit, where Lamarck was born in 1744.

Lamarck was a contemporary of Buffon, Jussieu, Haüy, Cuvier and Geoffroy St. Hiliare; also Rousseau was a friend of his youth. He was busy proclaiming a universal theory of evolution within the walls of the Museum d'Histoire Naturelle while the Reign of Terror was raging in the streets of Paris without. For it must be noted that his was not a theory of organic evolution alone, as we now know it, but, he claimed, "that the minerals and rocks composing the earth's crust are all of organic origin including even granite" (p. 120).

His first scientific work was as a Botanist and his "*Flore Française*," published in 1778, in three volumes, was highly appreciated, won him a place in the Academy and the familiar title of "the French Linné."

His later work in Zoology is also excellent. "There has never been any lack of appreciation of his labors as a systematic zoologist," says his biographer (p. 180).

The same may be said of his descriptive work in Paleontology His "*Coquilles fossiles des environs de Paris*" will ever rank on a par with Cuvier's "*Ossements Fossiles*" among the foundations of the new science of Paleontology. But we note that it was Cuvier who first recognized in the fossil bones of the Paris basin evidence of *extinct* species of organisms formerly inhabiting the earth; while it was Lamarck, the transformist, who denied "that any species can really be lost or extinct" (p. 129). His speculations in Geology were crude and not in advance of his age; they no longer have a place in science. In general Physiology his speculations about spontaneous generation, subtile vapours and fluids, orgasm and caloric dropped out of sight with the advance of scientific knowledge. His speculations in physical science are described by his biographer as "physico-chemical vagaries." His strenuous advocacy of theories of all kinds, without taking the pains to adapt them to the opinions of his fellow scientists, or to establish their verity by actual observation, seems to have been the chief reason for the neglect which they and he suffered in his own time.

With the advance of scientific knowledge others have discovered laws, regarding the processes of evolution, which were distinctly formulated by Lamarck, and it is the full exposition in English of Lamarck's own view upon evolution that constitutes the chief value of this volume. Although readers will still differ as to the place Lamarck deserves among the founders of the modern theory of evolution, the reading of his words clearly demonstates that he had in mind the construction of a fully elaborated scheme of factors to account for the modification of organic beings by slow and gradual variation into the diverse organic species now living on the earth. The Lamarckian factors *use and disuse, effort* (or felt-want or need), *direct effect of environment* and *inheritance of acquired characters* are recognized forces at work in determining organic variation. There can be little doubt, also, that *growth force*, which Cope has named Bathmism, is a factor of varying, in so far at least as varying is a normal function of all living and therefore growing bodies. These factors, however, without natural selection, do not constitute a complete scientific theory of organic evolution.

In the preface, the biographer states that "For over thirty years the Lamarckian factors of evolution have seemed to me to afford the foundation on which natural selection rests, to be the primary and efficient causes of organic change, and thus to account for the origin of variations which Darwin himself assumed as the starting point or basis of his selection theory" (pr. vii).

But may it not also be said that before Darwin no theory of evolution ever succeeded in crossing the line between philosophic speculation and natural science? The theory of natural selection first won for evolution a place among the sciences.

At first Lamarck believed that species were constant in nature, but as he tells us in the appendix to "*Système des Animaux sans Vertébrés*" (written probably as late as 1801), "I am now convinced that I was in error in this respect, and that in reality only individuals exist in nature" (p. 249), "all the modifications that each living being will have undergone as the result of change of circumstances which have influenced its nature will doubtless be propagated by heredity (*génération*). But as new modifications will necessarily continue to operate, however slowly, not only will there continually be found new species, new genera, and even new orders, but each species will vary in some part of its structure and its form" (p. 250).

It was, however, not till the appearance of the "Origin of Species" that a scientific way of accomplishing this result was discovered. It is natural selection which explains how it is that organisms varying by whatever means, can have their characters preserved when favorable,—rejected when useless, and thus indiscriminate variability can be reduced to the systematic evolution,

of always closely adjusted organisms, that we see taking place in nature.

The imperfection of the theory as a whole does not, however, detract from the honor due to Lamarck for the first announcement of the particular laws of evolution for which he is already famous.

We cannot agree with Professor Packard in describing Darwin as "*pushing entirely aside the Erasmus Darwin and Lamarckian factors of change of environment*" (p. 382).

The following quotations from the "Origin of Species" sufficiently testify to Darwin's full appreciation of the effects of change of environment:

In chapter v of the "Origin," on "Laws of Variation" Darwin distinctly states, that the facts of variation "lead to the conclusion that variability is generally related to the conditions of life to which each species has been exposed during several successive generations." "The direct action of changed conditions leads to definite and indefinite results," and "when the variation is of the slightest use to any being we cannot tell how much to attribute to the accumulative action of natural selection and how much to the definite action of the conditions of life." And not to stop with these quotations it was the same author of the theory of natural selection who adds, "In one sense the conditions of life may be said not only to cause variability, either directly or indirectly, but likewise to include natural selection, for the conditions determine whether this or that variety shall survive." (Darwin's Origin of Species, vol. i, pp. 164–167. Appleton edition, 1897.)

Lamarck's great merit consists in his unswerving advocacy of the theory of specific mutability, and the clear formulation of several very important factors of organic evolution. But his theory includes several factors which science cannot authenticate, and it lacks factors which are essential to a working hypothesis of organic evolution.

We close the book, after a careful reading, with the conviction forced upon us that Lamarck's theory, pure and simple, is not an adequate substitute for the more complete and rational Darwinian theory of evolution.

Chapters are added presenting Lamarck's views on the evolution of man, his thoughts on morals and the relation of science to religion, and a brief summary of the views of the more important Neo-Lamarckians. A complete bibliography of Lamarck's works is published at the end. H. S. W.

2. *Congrès Géologique international; Comptes Rendus de la VIII^e^ session, en France* (by the President, ALBERT GAUDRY, and general secretary, CHARLES BARROIS), two volumes, pp. 1–1314, figures 1–84, plates i–xxii. Paris, 1901. These two volumes give an account of the proceedings of the Congress held at the time of the Exposition in Paris in 1900. Besides the reports of committees a larger than usual number of scientific papers appear.

Among the more important subjects discussed by the Congress or represented in communicated papers, are the Report on Petrography and discussion associated; the report of the international committee on glaciers; a paper by Sir Archibald Geikie, on International coöperation in geologic investigation; the establishment of a committee, upon the suggestion of Dr. P. Œhlert for devising means for the publication of paleontologic types and original descriptions of fossils; a paper on bases of geologic classification by Prof. T. C. Chamberlin; a large number (76) of important papers on geology—and the *Lexique Pétrographique* of F. Loewinson-Lessing, occupying the last 300 pages of the second volume.

C. D. Walcott presented a paper on pre-Cambrian fossiliferous rocks. H. F. Osborn one on methods of precision in the study of fossil vertebrates, in which is given a Tableau des horizons stratigraphiques typiques et des horizons homotaxiques de l'Europe et des États-unis.

The discussion of the Report of the Committee on Stratigraphy led to the approval of the proposition to adopt for international nomenclature the prefexis *paleo-*(or *eo-*) *meso-* and *neo-* in subdividing *systems* into *series;* thus the divisions of the 3d order of the Devonian system become Eodevonian, Mesodevonian, and Neodevonian, leaving for each country to determine the particular formations (etages) to be included in each series.

The following international committees with their American representatives were appointed: Comm. des lignes de rivages—Dawson (Canada), Chamberlin (U. S.); Comm. de Coöpération internationale—Chamberlin, Walcott; Comm. de Réproduction des types fossiles—Walcott, Williams; Comm. de Pétrographie—Adams (Canada), Hague, Iddings, Pirsson (U. S.). H. S. W.

3. *Preliminary Description of the Geology and Water Resources of the Southern Half of the Black Hills and adjoining Regions in South Dakota and Wyoming;* by NELSON HORATIO DARTON. U. S. Geol. Survey, 21st Annual Report, Part IV, pp. 491–599.—The Black Hills country is an epitome of North American geology and is probably destined to occupy a larger space in text-books and courses of instruction than any other area of similar size within the United States. For this reason the Black Hills geology deserves all the labor that is necessary to make it accurate and complete; further, the publications regarding it should be well illustrated and written with a view to their use by general readers. These preliminary papers by Mr. Darton are in the main well up to these requirements.

In the present paper some new facts are added to the geological history of the Mesozoic rim of the Black Hills uplift. The uppermost layer of what has been regarded as Carboniferous is proved to be Permian; the Red Beds and the marine Jura have been separated and subdivided; part of the Atlantosaurus Beds (fresh-water Jura) of Marsh are named Beulah shales (from Beulah post office in the Trias?). The idea advanced by Ward

that these shales mark the close of the Jurassic is here temporarily accepted. The reviewers believe, however, that the Jurassic also includes the overlying series of sandstones and shales (the "Lakota") which are assigned to the Cretaceous by Mr. Darton. Some variation in the deposits are to be expected, but there is no decided physical break and the presence of typically Jurassic fossils, Stegosaurus, Camptosaurus, etc., collected by Wieland, cannot be overlooked. The testimony of the fossil plants opposes nothing if it does not support this view. At the top of the "Lakota" is a very significant layer of limestone—the "Minnewaste." That the Jurassic closed here, and that subsequently markedly new conditions of plant and animal life prevailed, seems probable. The overlying series of soft rocks, the "Fuson" formations with scattering dicotyls, may, therefore, better represent Lower Cretaceous, followed by the Upper Cretaceous Dakota sandstone.

As regards the Tertiary sediments, the report contains much that is new, interesting and important. It is the first serious attempt to give in detail the distributional relations of these beds to the original dome, and it is a matter of some surprise to learn the extent to which the dome was originally covered by them. Mr. Darton remarks (p. 558): "They are found up to high altitudes in the vicinity of Lead at an elevation of over 5,200 feet and on the north end of the Bear Lodge Mountains more than a thousand feet higher." A Post-Oligocene uplift amounting to several thousand feet, and according to Mr. Darton equal to the present upslope of the plains, has taken place.

Many of the facts brought out in the present work concerning these deposits cannot fail to be of great interest at this particular time on account of the discussion now in progress regarding the manner of deposition not only of these beds, but practically the whole of the western fresh-water Tertiaries. Mr. Darton does not hesitate to express his belief that they represent true lacustrine deposits as opposed to the flood-plain and aeolian hypotheses. As regards the eastern barrier of the waters of the White River lake, about which there seems to be so much doubt, Mr. Darton says (p. 559): "The eastern margin of this lake has not been traced for any distance, but there is no great difficulty in seeing that it consisted of low hills of Pierre shale and Fox Hills beds against which the Tertiary formations now abut to the east." It is to be regretted that the author has not seen fit to enter somewhat more fully into a discussion of the evidences which led him to conclude that these beds are of purely lacustrine origin.

The facts attending the deposition of the mammalian fossils in these beds are briefly considered. The attempt to introduce new names for the old, well-known and well-established subdivisions of the Tertiary deposits is open to criticism. These subdivisions have been made upon the very best and most conclusive faunal evidences, appropriate and widely accepted names have been applied to them and there seems to be no reasons for changing

them unless they can be shown to be wrong. One important division of the White River series, the Protoceras beds, has been entirely omitted from the report.

The practical utility of the work in question in the way of application of the information gathered to the great problem of an adequate water supply for the large semi-arid region which it covers, can scarcely be overestimated. If proper advantage is taken of the knowledge which this report affords, it is likely to yield many fold what it has cost to collect and publish it.

J. L. W., G. R. W., H. E. G.

4. *The Newark System of Pomperaug Valley, Connecticut;* by WILLIAM HERBERT HOBBS. With a report on Fossil Wood by F. H. KNOWLTON. U. S. Geol. Survey, 21st Annual Report, Part III, pp. 1–162 with 17 plates and 59 figures.—This small area exhibits the features common to the Newark system of the Atlantic slope, viz: a series of sandstones with interbedded traps, much faulted into monoclines of low inclination. In the Pomperaug area the unconformable contact of the Triassic with the underlying gneiss was revealed by digging and the contacts between the several members of the Newark series show plainly the extrusive character of the basalts. The deformation of the area has been studied and mapped in great detail (chap. IV). By careful attention to scarps, offsets, the development of slickensides and fault rock, the location of springs, etc., more than 250 dislocations have been mapped. Most of these faults fall into fine parallel series and the individual fault-planes are spared with remarkable uniformity. The fault-blocks range in size from "units" to composite blocks of different orders which correspond in shape with the unit block. The resemblance of the intersecting system of parallel faults to a system of compression joints suggests compression in an east-west direction as the course of the faulting. Professor Hobbs's study of faulting is an important contribution to our knowledge of the structure of the Newark beds.

Chapter V deals with the Degradation of the Pomperaug Valley and vicinity, and shows an interesting history of the development of drainage. The stream direction is believed to be largely controlled by preëxisting faults. Faults have undoubtedly had their influence on Connecticut physiography, but the argument that the stream courses, large and small, in this region owe their existence to fault-lines is not convincing, and when this theory is enlarged to account for the river-system of the entire State (Jour. Geol., vol. ix, No. 6, 1901) the present writer believes that it rests on insufficient data.

The fossil wood from South Britain, Conn., is referred by Mr. Knowlton to *Araucarioxylon Virginianum.* H. E. G.

5. *Influence of Winds upon Climate during the Pleistocene Epoch;* by F. W. HARMER. Quart Journ. Geol. Soc., vol. lvii, pp. 405-476, 1901, with 21 maps.—More than thirty years ago, Dr. Buchan suggested that alterations in the distribution of land and water during past epochs would have reacted on climate, and

modern geologists are accustomed to use this hypothesis in explaining the distribution of fossil fauna and flora. Mr. Harmer shows, on the other hand, that wide-spread climatic changes, sufficient to determine the physical and biologic character of a region, may be produced by variations in the relative position of areas of high and low barometric pressure. The former humid condition of the Sahara and of the Great Basin, the existence of the Mammoth on the shores of the Polar Sea, the non-glaciated Alaskan regions, and the secular variations of the European and American ice-sheets, are factors which have aided the author in determining the areas of low and high barometer and the prevalent storm-tracks of the Pleistocene Epoch. Many meteorological difficulties are avoided by adopting the hypothesis that the maximum glaciation of the eastern and western continents was not contemporaneous. While giving due weight to the older theories of the cause of the Glacial Age as well as to the more recent theories of Prof. Chamberlin and Dr. Ekholm, Mr. Harmer is "inclined to think that the minor variations of the Pleistocene, the pre-historic, and the historic periods may have belonged to one great series of events, and have been alike due to the cause which gives Great Britain its variable seasons at the present day, namely, to *alterations in the directions of the prevalent winds.*" H. E. G.

6. *The Relative Density of Fluid and Solid Magmas.*—The question as to whether contraction or expansion takes place when an igneous rock is formed by the solidification of a fluid magma, is one that had been often discussed in connection with volcanic theories. It is generally assumed that the former is the case, and the experiments of Barus, detailed in this Journal ((2), xlii, 498, 1891), are conclusive on the point. Further experiments have been recently carried on by C. Doelter. He shows that in all the cases investigated by him, as given in the table below, the density of the molten fluid is less than that of the corresponding solid rock; there being a difference of 0·2–0·3 in most cases. In order to obtain accurate results, he remarks that it is necessary to have the molten mass at a temperature considerably above that of fusion, so that its fluidity may be complete. In the case of melanite (lime-iron garnet), for example, which fuses a little above 900°, the experiment was tried between 1050 and 1100°. Instead of using a fragment of the same material in testing, a number of different minerals of appropriate densities, and with fusing points considerably above the temperature in question, were adopted. By noting which of these sank and which of them floated in the fluid, the density of the fluid was obtained with a fair degree of accuracy. The accompanying table gives the result for two minerals and five basic rocks. It will be seen that the density of the solidified material in the glassy form is considerably less than that obtained when solidification takes place slowly and the product obtained is more or less crystalline. Furthermore, the last density approximates towards the original

density, while the glassy solid corresponds pretty closely to the fluid in the same direction. These latter results are what were to have been expected.—*Jahrb. Min.*, ii, 141, 1901.

Mineral or Rock.	Original density.	After ignition.	Fluid.	Rapidly solidified; glassy.	Slowly solidified; crystalline.
Melanite	3·75	----	3.55 –3·6	3·55–3·60	3·65 –3·7
Augite	3·29 –3·3	----	2·92	2·92–2·95	3·2 –3·25
Limburgite	2·83	2·85–2·88	2·55 –2·568	2·55–2·568	2·75 –2·78
Lava, Etna	2·83	2·84	2·586–2·74	2·71–2·75	2·81 –2·83
Lava, Vesuvius	2·83 –2·85	2·84–2·87	2·68 –2·74	2·69–2·75	2·775–2·81
Nephelinite	2·735–2·745	2·75	2·70 –2·75	2·686	2·72 –2·75
Leucitite	2·83	----	2·60 –2 68	2·68–2·72	2·75–2·787

7. *Das Siebengebirge am Rhein;* by H. LASPEYRES, Mitth. aus dem Min. Institut Univer. Bonn, xii Theil.; Verh. d. nat. Ver. der preuss. Rheinl., lvii Jahr. 1900, Bonn 1901, 8°, pp. 471 with color. geol. map and 23 figs.—This work is a very careful and detailed description of the local geology of the well-known Siebengebirge. Since this is a volcanic group of mountains, so the greater part of the memoir treats of the petrography of the igneous rocks, but in addition the sediments are well described and such topics as the physiography, the local mineralogy, etc. receive adequate treatment. The work of former investigators is considered and a great amount of new material introduced. It is, in fact, a very complete geological hand-book of the region and, together with the excellent detailed map which accompanies it, will be found of great service to every visiting geologist.

L. V. P.

8. *New Mineral Names.*—A minute examination of the original MANGANOCALCITE of Breithaupt by Breusing has confirmed the results of Rammelsberg and Des Cloizeaux that it is a mixture of a carbonate and a silicate. The author shows further, however, that the silicate belongs to the triclinic system and has the probable composition $H_2Mn_3(SiO_3)_4+H_2O$. For this manganese silicate the name *agnolite* (agnolith) is proposed. It is related to inesite, which, however, contains calcium and has a somewhat different ratio.—*Jahrb. Min., Beil. Bd.* xiii, 265.

MANGANOSPHÆRITE is a carbonate of iron and manganese not far from the oligonite of Breithaupt. It is described by Busz from the Louise mine near Horhausen, Westerwald, Germany. The composition corresponds to $3FeCO_3{\cdot}2MnCO_3$. It occurs in globular aggregations and fibrous forms, filling cavities and narrow cracks in basalt; hardness 4·5 to 5; specific gravity 3·63. *Jahrb. Min.* ii, 129, 1901.

ESMERALDAITE is a hydrous iron sesquioxide described by A. S. Eakle from Esmeralda county, Nevada. It occurs in pod-shaped masses of a coal-black color, surrounded by a yellowish brown

earthy material consisting of a siliceous limonite. The black mineral has a vitreous luster and is translucent in thin edges; it is brittle, with conchoidal fracture and gives a yellowish brown streak. The hardness is 2·5 and specific gravity 2·578. An analysis by W. T. Schaller gave:

Fe_2O_3	H_2O (110°)	H_2O (over 110°)	Al_2O_3	CaO	P_2O_5	SiO_2	Organic	
56·14	15·94	10·24	5·77	3·35	4·49	2·05	1·37	= 99·35

If all the substances shown in the analysis, except the Fe_2O_3 and H_2O, are considered as impurities, the percentage composition becomes: Fe_2O_3 68·20, H_2O 31·80 = 100. This corresponds to $Fe_2O_3 \cdot 4H_2O$.—*Univ. Calif., Bull Geol.*, ii, 315, 1901.

9. *Mineralogy of California.*—Recent issues in the series of the Bulletin of the Department of Geology of the University of California (vol. ii, pp. 315–320 and 327–348) contain contributions to the mineralogy of the State. A. S. Eakle describes fine crystals of datolite, also pectolite occurring in veins of the serpentine of Fort Point, San Francisco; analyses by W. T. Schaller are added. The same author describes the new hydrated iron sesquioxide, esmeraldaite (see p. 72); the occurrence of coquimbite at the Redington mine, near Knoxville; also crystals of the lead telluride, altaite, with the forms *a* (100), *o* (111), *β* (332) from Sawmill Flat, Tuolumne County.

W. C. Blasdale shows that the green amphibole of the Coast Range in the neighborhood of Berkeley agrees with actinolite in physical characters though somewhat peculiar in chemical composition, alkalies being present to the amount of 2½ per cent. A blue amphibole from the same region comes very near to glaucophane but differs rather widely from the crossite of Palache. Descriptions are also given of tremolite, chlorite, talc and other species.

The Mesa Grande Mountains in San Diego County have recently yielded beautiful crystals of red and green tourmaline, occurring in lepidolite and in the associated quartzite. The crystals are often well terminated and many of them are of considerable size, transparent and of great beauty. The variety rubellite is most common, but many specimens show the characteristic zonal arrangement of color both concentric and in horizontal bands. (See further remarks by Kunz on the Production of Precious Stones in Min. Resources of the U. S. for 1900.)

10. *New localities of Nephrite.*—A recently issued inaugural dissertation, by A. Dieseldorff, describes a series of rocks and fossils from Chatham island, as also from D'Urville and Stephens islands, New Zealand. Among other results, the author has made the interesting observation that nephrite occurs *in place* in serpentine as the mother rock on D'Urville island. This, as he notes, is the first time that nephrite has been definitely located, although obtained so frequently from New Zealand. The nephrite nodules occurring in the serpentine show uralitization,

as proved both by microscopic structure and by composition; in other words, the material is uralite-nephrite. Nephrite was also obtained in rolled masses from the same locality and at other points, but in these cases showed no alteration, so that its composition corresponded closely to normal actinolite.

It is interesting to note in this connection the remarks by G. F. KUNZ, on the recent discovery of nephrite in Siberia. He says:* "This search for nephrite in Siberia was greatly stimulated in 1897 by a command from the imperial house of Russia that material be obtained for the sarcophagus for the remains of the late Alexander III. L. von Jascewski, in charge of the Siberian division of the geological survey of Russia, made three trips to the eastern Ural Mountains for the purpose of discovering larger masses of nephrite than had been known, and if possible, of finding nephrite in place. After thoroughly studying the deposits and obtaining masses of the material in the region of the Onot, which had been visited by Alibert in 1850 and Permikin in 1865, he then wended his way towards the region of the Chara Jalga, in the bed of which river he discovered some masses of nephrite measuring 12 feet in length and 3 feet in width, but even more important than this, he found a ledge of the primitive nephrite of magnificent green color—for the first time recognized in situ in Siberia. Enough of the material was obtained from the bowlders in the streams so that for the past three years the Imperial Lapidary Works at St. Petersburg have been making a small pavilion or canopy to be placed over the tombs of the Czar and his wife. This pavilion or canopy measures 13 feet in height, and is made up entirely of nephrite and rhodonite, of which latter material the entire sarcophagus had already been made for Czar Alexander II."

11. *The World's Largest Diamond.*—The gigantic diamond found in 1893, at Jagersfontein in South Africa, first called the "Excelsior" and weighing in the rough state 971¾ carats, was exhibited at the Paris Exposition in 1900 cut as a brilliant and valued perhaps at $2,000,000. It is now called the "Jubilee Diamond," in honor of the celebration of the sixtieth anniversary of the accession of Queen Victoria. G. F. Kunz says† in regard to it: "It far surpasses any diamond known, not only in size, but in its faultless perfection of color, luster, and water, and it has been cut with the most skillful modern appliances, so that it is an absolutely peerless gem. The Jubilee diamond weighs 239 French international carats of 205 milligrams. The Orloff of Russia weighs 194½ carats; the Regent of France, 136¾ carats; the Imperial, 180 carats, and the Koh-i-nûr, 102¾ carats. The Orloff, moreover, is a quaint, oriental-cut stone, and if it had been cut as a brilliant would not have weighed over 140 carats. Moreover, it is not flawless. The Regent has a minute flaw, and

* The Production of Precious Stones in 1900, from Mineral Resources of the U. S. for 1900) U. S. Geol. Survey).

† Loc. cit.

the Koh-i-nûr has a grayish tinge. As regards purity, cutting, and color the Jubilee is actually perfect, and its form is so symmetrical that when placed on the small truncated apex of its basal pyramid, the cullet, it stands perfectly balanced, though measuring 1⅝ inches in length, 1⅝ in breadth, and 1 inch in depth. As originally found, it was an irregular crystal of gigantic size, 971¾ carats. The original crystal had a black spot about the center of the mass, but by cleaving it in two this was removed, and the Jubilee diamond was cut from the larger half.

III. Zoology and Botany.

1. *Reports on the Natural History of Porto Rico*, Bulletin of the U. S. Fish Commission for 1900.

Among the additional reports received are the following:

The Stony Corals of Porto Rican Waters; by T. W. Vaughan. Pages 289–320, 38 plates.—This is a valuable report including descriptions of a considerable number of the common West Indian reef-corals (16 species), and a few from deeper water, illustrated by heliotype reproductions of photographs, except plates i, ii, which are from good drawings of the smaller species. The absence of many of the common West Indian corals is very noticeable and indicates merely that the collections of reef-corals were made without much care or energy, on this expedition. The number should have been at least doubled easily.

Many of the plates are excellent, but some are very unsatisfactory, owing either to the poor quality of the photographs used, or else to faulty reproduction. Among the least satisfactory are those of *Orbicella acropora*, *Favia fragum*, *Agaricia*, sp. and "*A. elephantotus.*" But all might, just as well, have been as good as the best.

The nomenclature adopted is the same as that used by the author in his former paper, on the fossil corals of Curacoa, etc. (1901), and he here repeats the same arguments to sustain his usage. As I have recently printed a paper on the West Indian corals,* in which I have criticized some of his conclusions and adopted a different nomenclature, in many cases, it will not be necessary to go into the details of this subject here. But it may be well to call attention to some of the more important points of disagreement, and which relate to common species.

I.—*Acropora, 1815, versus Isopora, 1878,=Madrepora authors:*—It is well known that Linné (Syst. Nat., ed. x, 1758) did not include in his genus *Madrepora* any recognized species of the Lamarckian genus of that name, but erroneously placed *M. muricata* (in which several species were included) in his genus *Millepora*, although it agrees with his definition of *Madrepora*.

* Variations and Nomenclature of Bermudian, West Indian, and Brazilian Reef Corals, with notes on various Indo-Pacific Corals, Trans. Conn. Acad. Science, vol. xi, pp. 63, 168, 26 plates, Dec., 1901.

He corrected this mistake in the ed. xii, p. 1279, where *Madrepora muricata* appears. Therefore, if we follow the strict rules of priority and go back to ed. x of Linné, we cannot use the name for this genus.*

The substitute-name that has the prior claim for adoption, and which seems available, is *Acropora* Oken, 1815. This originally included three generic types :—1st, *Pocillopora damicornis ;* 2d, a *Porites ;* 3d, *A. muricata* (L.). The first two having been eliminated by Link, 1807, and Lamarck, 1816, *Acropora* should be restricted to the third species, which is the true West Indian *muricata.* Vaughan uses the much later and objectionable name *Isopora* Studer, 1878, originally applied to a small section of the genus in which single, prominent axial corallites do not form the tips of branches.

In my work, cited above, I have restricted *Madrepora* to the types, *M. oculata* L. and *M. prolifera* L., ordinarily referred to *Lophohelia* and *Amphihelia* E. and H.

II.—*Mœandra, 1815, versus Platygyra, 1834 :*—It seems necessary to restrict *Meandrina* (Lam., 1801) to the type *meandrites* (L.)=*pectinata* Lam., as claimed by Vaughan and others. The next generic name, in order of publication, is *Mœandra* Oken, 1815, in which the first species (*areola* = *Manicina areolata,* authors), and also the second and fourth, belong to this group. Ehrenberg, also, definitely adopted this name nearly in the sense used here. Vaughan assumes that *M. meandrites* should be considered the type of *Mœandra,* and thus makes it a synonym of *Meandrina.* This is not logical. Oken includes in this genus one of the *meandrites*-group by mere accident, it being erroneously referred to as a variety of a true *Mœandra* (*M. labyrinthiformis* (L.)=*Diploria*), while the four other species were of the *Diploria* and *Cœloria* groups. Moreover, he founded, in the same work, a new genus (*Pectinia*) for the *meandrites*-group. This of itself would show that he did not intend to include *meandrites* in *Mœandra.* Hence I have adopted *Mœandra* Oken, in place of *Meandrina* of later authors, but I have reunited to the genus *Manicina, Diploria,* and *Cœloria* of Edw. and Haime, for they have no structural or generic differences. *Platygyra,* used by Vaughan, was given to a subdivision of *Mœandra* by Ehr., 1834, and would be valid had not *Mœandra* prior and better claims.

III.—*Mœandra cerebrum* (*Ellis and Sol., 1786*) *versus Platygyra viridis* (*Les., 1877*) :—This is the common large, rounded, simple-ridged brain-coral that has had many and varied names, but is more commonly called *Mœandrina labyrinthica, M. strigosa* Dana, or *M. sinuosa* Les. Evidently none of the early names used for this species are available, except *M. cerebrum* of

* In a letter received after this review was put in type, Mr. Vaughan authorizes me to state that he now agrees with me that *Acropora* should be used in place of *Isopora,* and in the restriction of *Madrepora* to the *oculata*-group. Also in the reunion of *Diploria, Manicina* (auth.), *Cœloria,* and *Platygyra* = *Mœandra* in one genus; in the use of *Mœandra,* in place of *Platygyra;* and in the use of *O. annularis* instead of *O. acropora.*

Ellis and Solander, which was clearly based on the most common form of the species. Their description, though brief, is characteristic, and they also give the vernacular name, "Brainstone," which is still in use in the Bahamas and Bermudas. Vaughan adopts *viridis*, the name of one of the color varieties of *M. sinuosa*, described by Lesueur, 1817. There can be no certainty that this variety pertained to *M. sinuosa*, for Lesueur gave to it no characters except the green color. It is well known that the green color, so frequent in coral animals, is generally due to a parasitic unicellular vegetable organism, and it may occur in almost any species of reef corals, so that one can never be certain of the difference or identity of two allied corals having this color, even in the same locality, without studying the hard parts. On this account the name *viridis* should not be adopted for this species, for it was not connected with any specific characters and therefore has no claims for recognition, even if *cerebrum* were not available.

IV.—*Orbicella annularis versus O. acropora:*—Mr. Vaughan follows Gregory in adopting *acropora* (? Linné, ed. xii) in place of the long used name *annularis* Ellis and Sol. The *M. acropora* of Linné is utterly indeterminable. The locality was unknown, and the diagnosis so brief and vague that it applies equally well to any one of a dozen or more species of small astrean corals, both Pacific and Atlantic. Nor did Linné refer to any figure in earlier works. It is useless and unfortunate to try to apply the name to the present species and to displace a valid and long established name by one of extreme uncertainty. I do not know any good reason for such a course, in this case. The name *acropora* (L.) should be discarded as indeterminable, both generically and specifically. There is no certainty nor probability that the Linnæan species was the same as *annularis*, nor is there any good reason to believe that the *acropora* of Esper and of Edw. and Haime were the same as the *acropora* of Linné. It is certain that the contemporaries of Linné, like Pallas and Ellis, did not thus identify this species, for they described the *annularis* under other names. Had this species been what Linné had before him, he would undoubtedly have referred to Pallas, who had already well described it as *M. astroites*, for he referred to the other species of Pallas.

V.—*Porites polymorpha versus P. porites:*—Vaughan unites *Porites clavaria*, *P. furcata*, and all other branched West Indian forms under *Porites porites* Pallas. We cannot follow Vaughan in adopting *Porites porites* for it, for such a course would be contrary to the ordinary principles of elimination which he, himself, employs like others in similar cases. It is true that Pallas and all writers previous to Link (1807) included nearly all the species of *Porites* then known under the name *Madrepora porites*, which was a collective or generic group. Esper eliminated one species as *M. conglomerata*, and another as *M. arenosa*. Link eliminated another, the present form, by naming it *polymorphus*. Therefore,

the specific name *porites*, if used at all, should be applied to one of the remaining species of those mentioned by Pallas, as varieties. Pallas mentions *first* in his description (p. 324) a massive, gibbous species "massæ, gibbæ, tuberosæ, tunicatæ," and on p. 395, "Notæ," he speaks first of "massa informes, gibbas," "ex India," with stars subequal to those of *Mad. astroites* = *Orbicella annularis*. This East Indian, gibbous, massive species, with large stars, was evidently a *Rhodaræa*, probably *R. calicularis* (Lam., diameter of calicles 4^{mm}). Therefore, it seems best to restrict *porites* to that species and call it *Rhodaræa porites*, thus avoiding the repetition of *porites* and conforming with the principle of recognizing prior eliminations at one and the same time. None of the species of true *Porites* have the "stars" much more than 1·5^{mm} in diameter, rarely 2^{mm}.

Mr. Vaughan agrees with Brook and the writer in uniting all the West Indian forms of *Isopora* (= *Acropora*) as varieties of a single species (*Muricata L.*). The principal varieties are *palmata*, *flabellum*, *cervicornis*, and *prolifera*. To these I have recently added others: *columnaris*, *cornuta*, *perampla*, *palmato-prolifera*, *flabello-prolifera*, *surculo-palmata*, etc. A. E. V.

2. *The Alcyonaria of Porto Rico;* by C. W. Hargitt and Chas. G. Rogers. Pages 265–287, 4 plates and cuts in the text, Dec., 1901.—This is a very useful report, though the number of species treated is not large. In the first part there is a good general synopsis of the families and genera of Alcyonaria, with diagnoses of the genera found in the West Indies.

The species described and figured include many of the common shallow water forms, as well as a considerable number from deep water, several of which are new. A. E. V.

3. *The Mollusca of Porto Rico;* by Wm. H. Dall and C. T. Simpson. Pages 351–524, 5 plates, received Dec., 1901.—This is an important report, for it gives descriptions of a large number of species, hitherto scattered through a great mass of literature. It includes 653 species, of which 107 species are terrestrial; 42 are described as new marine forms. A large number of species are here, for the first time, recorded from Porto Rico. A. E. V.

4. *The Birds of North and Middle America;* by Robert Ridgeway, Part I, *Family Fringillidæ*, Bulletin of the U. S. Nat. Museum, No. 50, 1901, 715 pages, 20 plates.—This rather elaborate report consists of a descriptive catalogue of the higher groups, genera, species, and subspecies of all American birds occurring north of the Isthmus of Panama, and also those of the West Indies and Galapagos Islands.

It amounts to a complete monograph of all the Fringillidæ occurring within these limits. A. E. V.

5. *Capillaranalyse beruhend auf Capillaritäts- und Adsorptionserscheinungen, mit dem Schlusskapitel: das Emporsteigen der Farbstoffe in den Pflanzen;* von Friedrich Goppelsroeder. Basel, 1901.—It is a familiar fact that when one end of a strip of bibulous paper is dipped in an aqueous solution of coloring mat-

ter, the water will ascend faster than the dye. Schönbein appears to have been the first to turn this interesting phenomenon to account in the laboratory. Among those who witnessed Schönbein's experiments in this field was the author of the present volume. His paper is a treasury of data collected during a protracted investigation of this and allied matters. In a subsequent notice we shall hope to give some of the more striking results reached as regards plants, but we meanwhile desire to call the attention of students of Biology to this important memoir, which fills a long felt want. G. L. G.

6. *Plant Life of Alabama.* An account of the Distribution, modes of Association, and Adaptations of the Flora of Alabama, together with a systematic Catalogue of the Plants growing in the state by CHARLES MOHR, pp. 1–921, with portraits of the author and of Thos. M. Peters.—As is stated also on the title page, this volume is a reprint of a volume published by the U. S. Department of Agriculture, prepared in coöperation with the Geological survey of Alabama. The Alabama edition presents also a sketch of the life of Charles Mohr, prepared by Eugene A. Smith, the State Geologist. W.

IV. ASTRONOMY.

1. *The Leonids in 1901.*—The leonid shower was apparently this year rather more pronounced than in the two previous years and about as strong as that in 1898. Observations were secured at the Yale Observatory on the nights of November 13, 14, 15 and 16, the latter three being clear throughout. The greatest observed frequency occurred on November 14 at about 16 to 17 hours mean time, or on the morning of Friday, November 15, civil reckoning, when a single observer noted about 50 per hour. Photographic records were obtained of two leonids, one of them at both the Observatory and a station 3 miles distant. This meteor described an orbit very closely accordant with that of the leonids in 1898. W. L. E.

2. *Leonids at Phoenix, Arizona;* by D. S. LANDIS, Observer, Weather Bureau. (Communicated.)—The leonids observed at Phoenix, Arizona, showed to fine advantage on the morning of the 15th, owing to a perfectly clear sky. The greatest display occurred about 5 A.M., local time. The showers were not constant, but came at intervals of about two minutes. A bevy would streak the sky for a few seconds, then the number would dwindle away to a straggling few here and there, until another shower would come on. Within ten minutes four profuse and distinct showers were noted.

Twenty leonids were counted within one minute flying over a space checked off by a house top. The angle of descent seemed to be about forty degrees from the perpendicular. The path of translation was due northwest, except in cases where violent explosion was apparent, causing deflection. In one instance an

explosion was noticed wherein the main part of the leonid was deflected to the southwest, and two zigzag lances of yellow flame darted off to the northeast.

The prevailing color was white. Some were tinged with yellow, a few were bluish, and others had tintings of red both on the head and edges of the wake of light. Most of the bodies showed a brilliant white center with purplish borders. One very large one resembled a six-inch globe of cankerous fire with spicules of red and yellow radiating from all points on the surface.

The path of light behind each body spread out in a feathery fan shape, and explosions were evident in the train of light, for the larger points would fly violently into a powdery haze, scintillate in a sort of luminous effervescence, and go out.

The first appearance of a leonid coming toward you from the southeast showed a reddish point of light which quickly merged into a yellow hue mixed with blue, then flared into an incandescent splendor. As the leonid approached, the point increased rapidly in size, some to apparently six inches in diameter, then tapered down to powdery sparks which invariably showed a violet cast before disappearing.

The sizes varied from mere beads of flaring white with thin iris-colored threads behind, to globes half a foot in diameter with explosive trains of variegated lights hundreds of yards in length.

The life of some of the larger leonids was fully five seconds from the time of the first point of light to the fading away of the luminous dust into darkness.

It would have been impossible to have counted the number, for they rained down from all parts of the heavens at intervals of about two minutes apart, and the descent continued until the morning light obscured them.

November 20, 1901.

3. *Leonids at Havre, Montana;* by C. W. Ling, Observer, Weather Bureau. (Communicated.)—A beautiful display of leonids, or shooting stars, was observed at this station this morning. When I stepped out of the door at 7.30 A.M. (75th meridian time) I looked up at the constellation Leo and saw four meteors in less than that many seconds. After I had filed my morning report, I met the night policeman, William Chestnut, who was waiting to tell me about the unusual number of shooting stars he had seen during the preceding hour. I explained to him what they were and showed him the point from which they radiated. We then watched these meteors for over half an hour and saw at least a hundred of them. Some were of great brilliancy, some were actually seen to radiate directly from the constellation Leo, and all seemed to emerge from within the sickle in that constellation. At intervals they came into the earth's atmosphere at the rate of one a second for at least six seconds. As long as a star could be seen in this constellation these shooting stars appeared and continued until the great circle of illumination shut off all further view of them.

November 15, 1901.